

marconi
instruments

TF 2330A
WAVE ANALYSER

Instruction Manual

NOTES AND CAUTIONS

ELECTRICAL SAFETY PRECAUTIONS

This equipment is protected in accordance with IEC Safety Class 1. It has been designed and tested according to IEC Publication 348, 'Safety Requirements for Electronic Measuring Apparatus', and has been supplied in a safe condition. The following precautions must be observed by the user to ensure safe operation and to retain the equipment in a safe condition.

Defects and abnormal stresses

Whenever it is likely that protection has been impaired, for example as a result of damage caused by severe conditions of transport or storage, the equipment shall be made inoperative and be secured against any unintended operation.

Removal of covers

Removal of the covers is likely to expose live parts although reasonable precautions have been taken in the design of the equipment to shield such parts. The equipment shall be disconnected from the supply before carrying out any adjustment, replacement or maintenance and repair during which the equipment shall be opened. If any adjustment, maintenance or repair under voltage is inevitable it shall only be carried out by a skilled person who is aware of the hazard involved.

Note that capacitors inside the equipment may still be charged when the equipment has been disconnected from the supply. Before carrying out any work inside the equipment, capacitors connected to high voltage points should be discharged; to discharge mains filter capacitors, if fitted, short together the L (live) and N (neutral) pins of the mains plug.

Mains plug

The mains plug shall only be inserted in a socket outlet provided with a protective earth contact. The protective action shall not be negated by the use of an extension lead without protective conductor. Any interruption of the protective conductor inside or outside the equipment is likely to make the equipment dangerous.

Fuses

Note that there is a supply fuse in both the live and neutral wires of the supply lead. If only one of these fuses should rupture, certain parts of the equipment could remain at supply potential.

To provide protection against breakdown of the supply lead, its connectors, and filter where fitted, an external supply fuse (e.g. fitted in the connecting plug) should be used in the live lead. The fuse should have a continuous rating not exceeding 6 A.

Make sure that only fuses with the required rated current and of the specified type are used for replacement. The use of mended fuses and the short-circuiting of fuse holders shall be avoided.

RADIO FREQUENCY INTERFERENCE

This equipment conforms with the requirements of IEC Directive 76/889 as to limits of r.f. interference.

Contents

INSTRUCTION MANUAL

No. EB 2330A

for

Wave Analyser

TF 2330A

including TF 2330AR

1970

MARCONI INSTRUMENTS LIMITED
ST. ALBANS HERTFORDSHIRE ENGLAND



Contents

Chapter 1 GENERAL INFORMATION

1.1	Features	...	...	...	4
1.2	Data Summary	...	...	...	5

Chapter 2 OPERATION

2.1	Preliminaries	...	...	...	6
2.2	Calibration	...	...	...	8
2.3	Measurement procedures	...	...	...	9
2.4	Measurement of modulation	...	...	...	13
2.5	Signal outputs	...	...	...	13
2.6	Applications	...	...	...	13

Decibel conversion tables	...	...	...	18
---------------------------	-----	-----	-----	----

Chapter 3 TECHNICAL DESCRIPTION

3.1	General	...	...	...	21
3.2	Circuit summary	...	...	...	23

Chapter 4 MAINTENANCE

4.1	Introduction	...	...	...	27
4.2	Screw fasteners	...	...	...	27
4.3	Removal of case	...	...	...	27
4.4	Access to printed circuit boards	...	...	...	27
4.5	A.C. mains input ranges	...	...	...	27
4.6	Performance checks	...	...	...	27
4.6.1	Test equipment required	...	...	...	28
4.6.2	Voltage accuracy check	...	...	...	28
4.6.3	Frequency scale accuracy check	...	...	...	28
4.6.4	B.F.O. frequency accuracy check	...	...	...	28
4.6.5	B.F.O. output check	...	...	...	29
4.6.6	Selectivity check	...	...	...	30
4.6.7	A.F.C. discriminator check	...	...	...	31
4.6.8	Carrier balance	...	...	...	32
4.6.9	Frequency response	...	...	...	32
4.6.10	Output resistance	...	...	...	32
4.6.11	Set reference	...	...	...	32
4.7	Cleaning rotary switches	...	...	...	32

Chapter 5 REPAIR

5.1	Introduction	...	...	...	33
5.2	Fault location - voltages and waveforms	...	...	...	33
5.3	Component location	...	...	...	34

Component layout illustrations	...	...	...	34
--------------------------------	-----	-----	-----	----

5.4	Realignment	...	...	...	38
5.4.1	Introduction	...	...	...	38
5.4.2	Test equipment required	...	...	...	38
5.4.3	Regulated power supply	...	...	...	39
5.4.4	100 kHz i.f. filters	...	...	...	39
5.4.5	Crystal discriminator alignment	...	...	...	40
5.4.6	Frequency scale alignment	...	...	...	41
5.4.7	Carrier balance	...	...	...	41
5.4.8	B.F.O. alignment	...	...	...	41
5.4.9	Overall frequency response	...	...	...	41
5.4.10	Calibration signal level	...	...	...	42
5.4.11	External meter check	...	...	...	42
5.4.12	Distortion check and alignment	...	...	...	42
5.4.13	Residual noise and hum	...	...	...	43

Chapter 6 REPLACEABLE PARTS

Introduction and ordering	...	...	...	45
---------------------------	-----	-----	-----	----

Chapter 7 CIRCUIT DIAGRAMS

Circuit notes	...	...	...	52
---------------	-----	-----	-----	----

Fig. 7.1	Power supply	...	...	53
----------	--------------	-----	-----	----

Fig. 7.2	Input stages	...	...	55
----------	--------------	-----	-----	----

Fig. 7.3	I.F. and output stages	...	...	57
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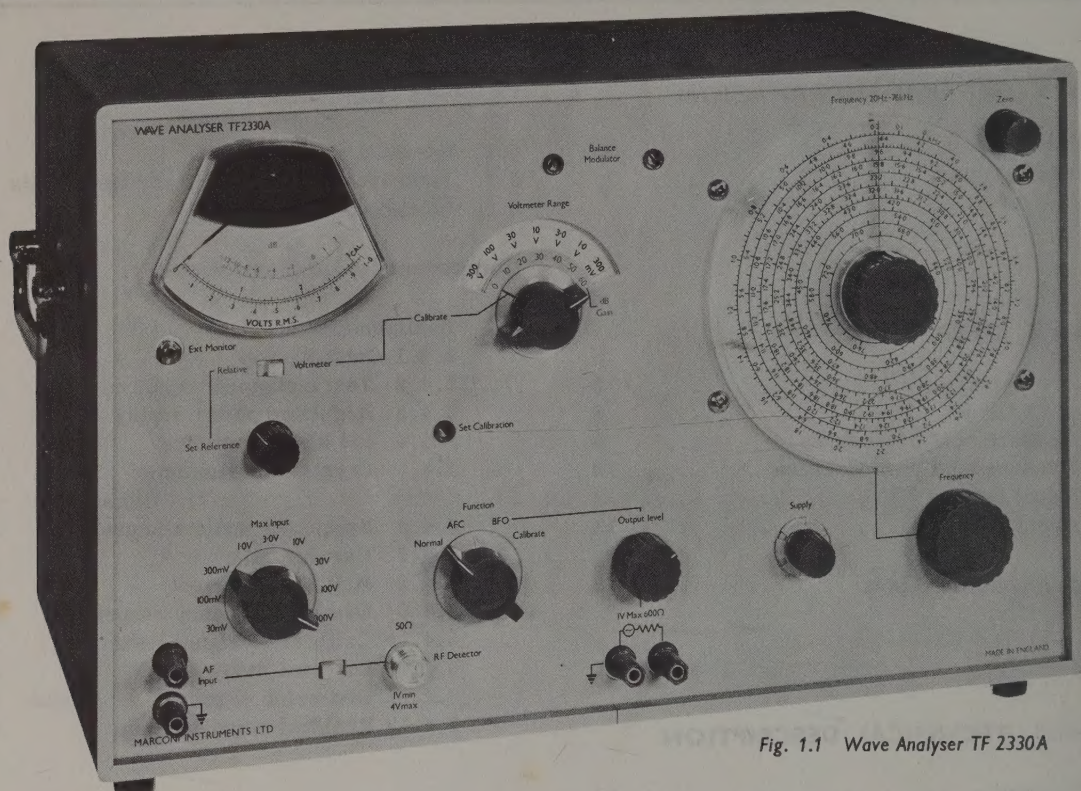


Fig. 1.1 Wave Analyser TF 2330A

1.1 FEATURES

The TF 2330A Wave Analyser provides comprehensive measurement facilities for the analysis of the performance of devices operating within the audio and ultrasonic frequency spectrum. The amplitude of each individual frequency component of a complex signal may be determined in terms of absolute voltage or relative to a fundamental datum level in decibels or in percent.

Basically the instrument comprises a sensitive narrow band tuned voltmeter covering the range $3\mu\text{V}$ to 300 V . With a bandwidth of 7 Hz it may be tuned to any frequency from 20 Hz to 76 kHz ; after initial tuning internal automatic frequency control may then be employed to lock it to the signal component to obviate continual retuning, thus ensuring accurate meter readings.

Amplitude modulated r.f. signals from 100 kHz to 500 MHz may be applied via the r.f. detector for measurements of envelope distortion at any depth of modulation up to 80% .

While a signal is being investigated a variable output voltage is available, having the same frequency as the signal component to which the analyser is tuned. When the component is not harmonically connected to any other known component of the input signal, this output may be applied to an external counter for a more accurate determination of its frequency.

Another function of the instrument is to provide a convenient facility for determining frequency responses. A beat frequency oscillator, controlled by the voltmeter tuning and in step with it, provides a variable output voltage which, when set, remains constant over the whole frequency range. By applying this signal to the input of a circuit and monitoring the output with the tuned voltmeter section the response of the circuit can be rapidly ascertained.

TF 2330AR is a rack mounting model which differs only in having a special case with flanges for fitting to a 19 inch rack.

1.2 DATA SUMMARY

INPUT FREQUENCY

Working range : 20 Hz to 76 kHz.

Accuracy : $\pm 1\%$, ± 5 Hz.

A.F.C. : Tuning remains locked to input frequency over ± 100 Hz drift.

AMPLITUDE RANGES

Waveform analysis

Range : Measurements down to -75 dB with respect to any fundamental level between 30 mV and 300 V. For fundamental levels below 30 mV, the measurement range is progressively reduced.

Selective voltage measurement

Range : 3 μ V to 300 V in 15 ranges of 30 μ V to 300 V f.s.d. in 1-3-10 sequence.

Accuracy : $\pm 5\%$ of full-scale.

SELECTIVITY ± 3.5 Hz bandwidth, at least 3 dB down, ± 40 Hz bandwidth, at least 63 dB down, ± 20 Hz bandwidth, at least 45 dB down, ± 80 Hz and above, at least 80 dB down.

INTERNAL NOISE & DISTORTION :

Residual hum and noise, and distortion to measured signal at least 80 dB down.

INPUT RESISTANCE : 100 k Ω on maximum attenuator settings between 30 mV and 1 V :
1 M Ω on settings between 3 and 300 V.

R.F. INPUT

Frequency range : 100 kHz to 500 MHz.

Input impedance : 50 Ω type N connector.

Amplitude range : 1 V to 4 V r.m.s. at maximum modulation depth.

RESTORED FREQUENCY OUTPUT

Range : 20 Hz to 76 kHz.

Output : Variable up to 2.8 V p-p out of 600 Ω source, when meter reads f.s.d.

B.F.O. OUTPUT

Range : 20 Hz to 76 kHz.

Output : Variable up to 2.8 V p-p out of 600 Ω source.

Response : Flat to within ± 0.1 dB over frequency range, terminated or unterminated.

RECORDER OUTPUT : 100 μ A $\pm 2\%$ into 2.5 k Ω . Recorder input to be isolated from ground.

POWER SUPPLY : Any voltage between 190-260 V and 95-130 V a.c.; 45 to 1000 Hz; 4 VA
OR 18-30 V d.c.; 110 mA maximum; positive earth.

DIMENSIONS & WEIGHT :	Height	Width	Depth	Weight
	11 in	18.5 in	11 in	29 lb
	(28 cm)	(47 cm)	(28 cm)	(13.1 kg)

Accessories supplied

Shielded Adapter, type TB 39868 (Greenpar type GE 51002) for converting input or output terminals to a BNC coaxial socket. MI code 43168-008.

Miniature Jack Plug, Rendar type MJP/600, for use in EXT MONITOR socket. MI code 23421-610.

Supply Lead for a.c. operation. MI code 43123-076.

2.1 PRELIMINARIES

In order to realize the full measurement accuracy of the wave analyser a preliminary calibration procedure is necessary. This, and the normal measurement techniques, are described in this chapter. Fig. 2.1 summarizes the functions of the controls and the measurement procedures in a form useful for subsequent quick reference.

Power Supply

The analyser may be operated from a.c. mains of a nominal 115 or 230 V, 45 to 1000 Hz; or from a d.c. supply of 18 to 30 V. For a.c. operation the stabilizer allows mains voltages of up to $\pm 20\%$ of the two nominal settings to be used. The instrument is normally dispatched with the 230 V setting unless specified to the contrary. In order to check or change the mains input settings see Section 4.3.

For measurements in the field, the instrument may also be d.c. powered from an external battery of from 18 to 30 V, the approximate current drain being 110 mA.

Fuses

Three fuses are fitted, two in the a.c. mains input circuit, the other in the h.t. supply to the stabilizer. The a.c. input fuses should be 50 mA rating for 230 V operation or 100 mA for 115 V. The other fuse is in circuit for both a.c. and d.c. operation and should be 160 mA rating. All fuses are 20 x 5 mm; the a.c. input fuses delay types, the h.t. fuse a quick-blow type.

Switching on

Before switching on :

- (1) Check that the mains transformer primary connections are correct for the local supply voltage. If they have to be changed remember that the a.c. input fuse must also be changed.
- (2) Set the MAINS/BATTERY slider switch on the rear panel to the position appropriate for the type of supply to be used.
- (3) Connect to the power supply.

For a.c. mains use the lead supplied, fitting the small 3 pin plug to the MAINS socket at the rear of the instrument. Initially it will also be necessary

to fit a suitable mains supply plug to the lead: note that the earth (or chassis) conductor has a yellow designation sleeve with a green circuit earth symbol, the neutral conductor has a black sleeve with a white 'N' and the line (or phase) conductor has no sleeve.

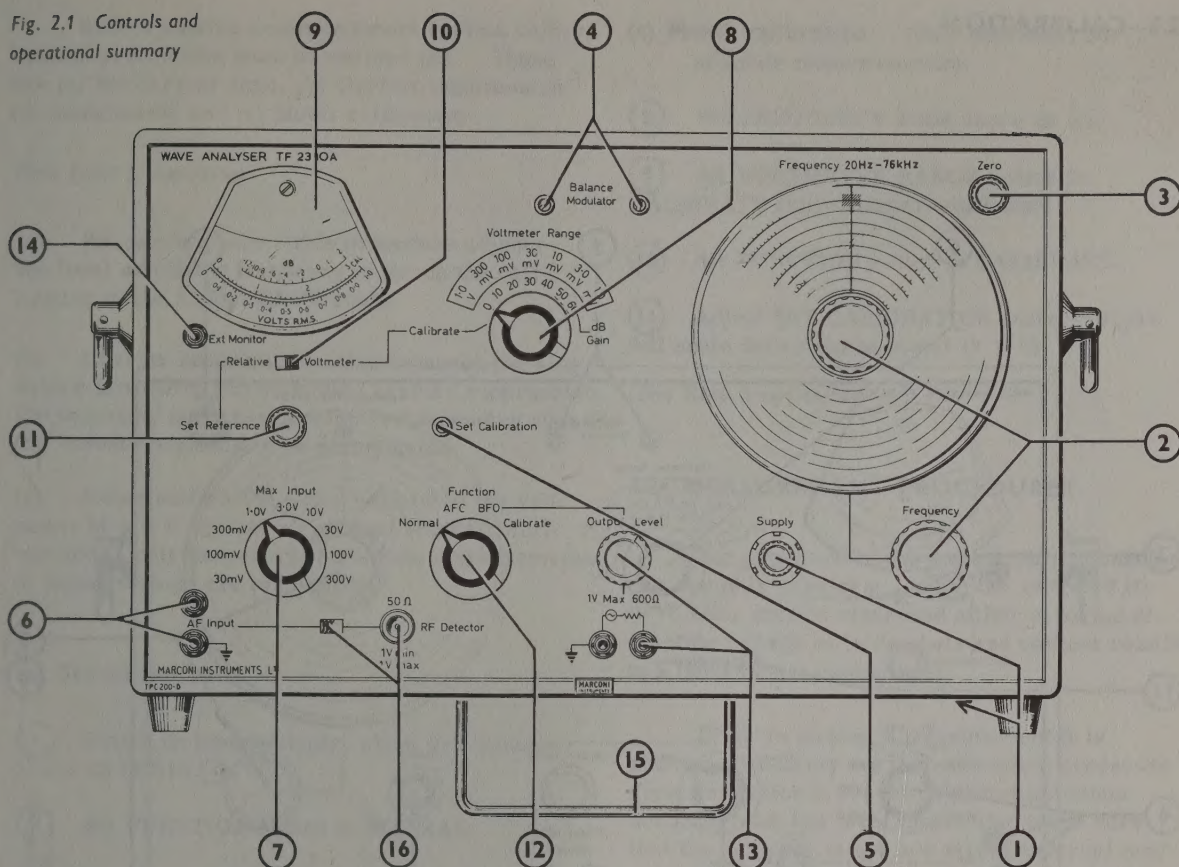
For d.c., connect the battery to the terminals at the rear of the instrument observing the required polarity; note that the '+' terminal is now connected to chassis. It is also advisable to disconnect the a.c. mains lead.

- (4) Check and if necessary adjust the mechanical zero of the meter.

Switch on by turning the SUPPLY switch on the front panel in a clockwise direction. Allow a few minutes for the oscillator to stabilize before zeroing the frequency scale.

- ① SUPPLY switch. Turn clockwise to switch on power supply. A.C. mains or battery power supply may be used, connections and fuses at rear of instrument.
- ② FREQUENCY control. Tune to required signal frequency. Use fine control on panel to give peak meter deflection. Scale is $8\frac{1}{2}$ turn spiral calibrated 0 to 76 kHz, with zero at outer end. Read scale at position of red marker.
- ③ ZERO control. Adjust for peak meter deflection to zero carrier with FUNCTION switch ⑫ at NORMAL, meter slider switch ⑩ at VOLTMETER, MAX INPUT switch ⑦ at 1 V, FREQUENCY scale at zero and no connection to input.
- ④ BALANCE MODULATOR presets. Adjust both for minimum meter deflection to suppress carrier after setting carrier zero ③
- ⑤ SET CALIBRATION preset. Adjust to give full scale (1.0 V) to calibrate meter, with FREQUENCY scale above 20 Hz, VOLT-METER RANGE ⑧ and FUNCTION ⑫ switches set to CALIBRATE.
- ⑥ INPUT terminals. Connect signal input 20 Hz to 76 kHz. maximum voltage 300 V (input stages protected by overload diodes).

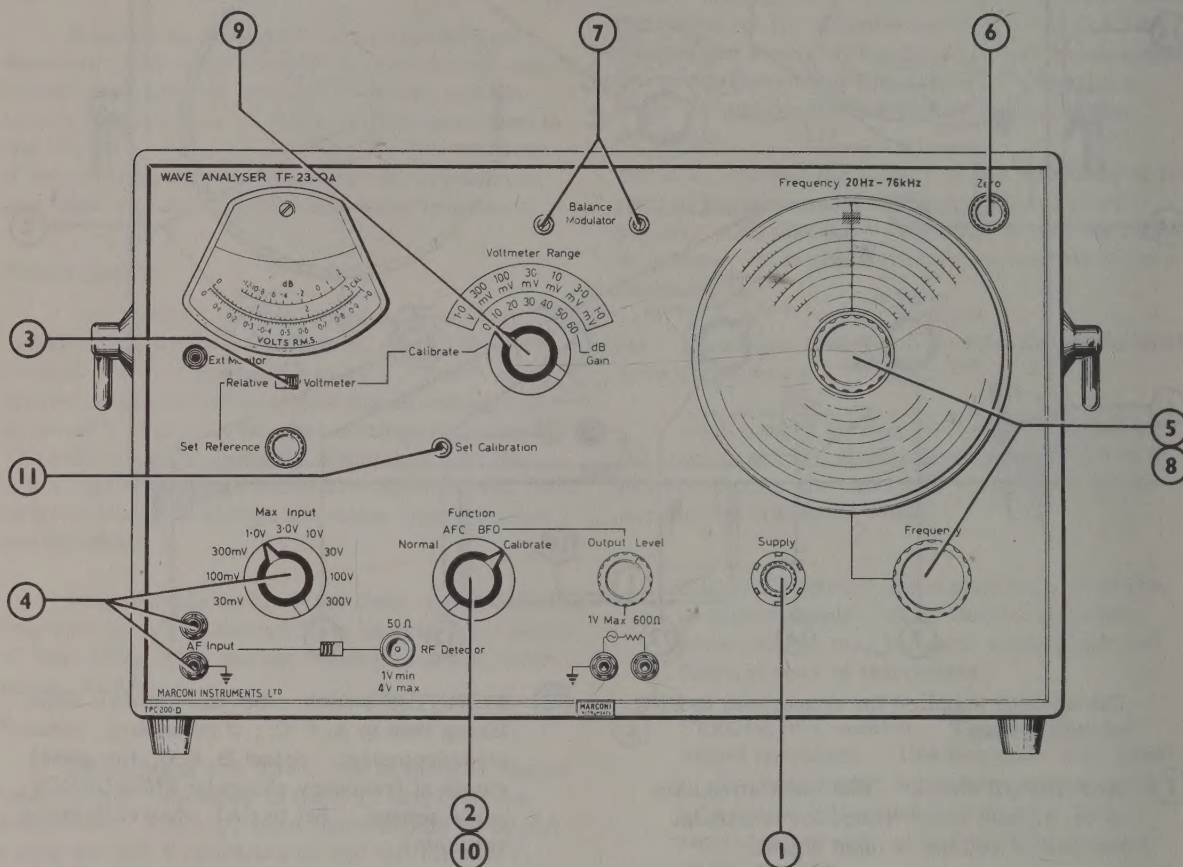
Fig. 2.1 Controls and operational summary



Use adaptor supplied for conversion to BNC coaxial socket.

- ⑦ MAX INPUT switch. Use input attenuator to set highest meter range for maximum component voltage of input signal.
- ⑧ VOLTMETER RANGE switch. Select range to give convenient meter deflection. Overall coverage of the seven ranges is set by MAX INPUT switch ⑦
- ⑨ METER. For absolute voltage measurement calibrate the voltmeter ⑤ then read voltage from convenient meter scale in conjunction with position of VOLTMETER RANGE switch ⑧
- ⑩ RELATIVE/VOLTMETER switch. Set for type of measurement required. RELATIVE for comparison of levels, VOLTMETER for absolute voltage measurement.
- ⑪ SET REFERENCE control. Level of input signal may be adjusted for relative measurements to give convenient meter deflection (0 dB or 1.0) as datum for fundamental component.
- ⑫ FUNCTION switch. Set to NORMAL while tuning then to A. F. C., if necessary, for measurements. Select B. F. O. for signal output at frequency shown by FREQUENCY scale setting. Set to CAL when calibrating voltmeter.
- ⑬ SIGNAL OUTPUT. Variable up to 1 V across 600 Ω . On NORMAL and A. F. C. positions the restored output has the same frequency as the input signal component to which the analyser is tuned. On B. F. O. position, an output of 20 Hz to 76 kHz set by FREQUENCY control, is available for use as a signal source. Use adaptor supplied to convert terminals to BNC coaxial socket.
- ⑭ EXT MONITOR socket. Output of 100 μ A into 2.5 k Ω available for external recorder having input isolated from ground.
- ⑮ SUPPORT. Hinges down to raise front of instrument.
- ⑯ R. F. DETECTOR socket for feeding in modulated r. f. signals from 100 kHz up to 500 MHz. Switched in or out of circuit by means of the adjacent switch.

2.2 CALIBRATION



Notes

- (1) During the initial calibration procedure you may notice considerable instability of the meter reading. This is only present when the FREQUENCY dial is set to zero (owing to the fact that noise in transistors is proportional to the inverse of frequency) and has no effect on actual measurements.
- (2) If the instrument is used for a long period with low frequency inputs, it is advisable to occasionally check the ZERO setting so that optimum frequency accuracy is maintained.
- (3) When making absolute voltage measurements over long periods it may be necessary to occasionally re-check the meter calibration to allow for slight changes in the gain of the i. f. amplifier.

Before making a measurement certain calibration procedures must be carried out. These are (a) Set carrier zero, (b) Carrier suppression (in modulator), and (c) Meter calibration.

(See Note 1 opposite)

(a) Set carrier zero - this procedure adjusts the local oscillator frequency to set up the calibration of the FREQUENCY scale.

(b) Carrier suppression - this balances the ring bridge modulator for maximum carrier suppression, the degree of suppression required depending upon the the lowest frequency to be investigated.

(c) Meter calibration - this calibrates the voltmeter at 1.0 V against an internal standard voltage and is only necessary if absolute measurements of signal voltage are to be made.

(a) Set carrier zero

- ① Switch on power supply, allow 2-3 minutes warm up before ⑥.
- ② Set FUNCTION switch to NORMAL.
- ③ Set meter slider switch to VOLTMETER.
- ④ Set MAX INPUT switch to 1.0 V or above and ensure no input connected.
- ⑤ Set FREQUENCY scale to zero (outer end of spiral).
- ⑥ Adjust ZERO control for maximum meter reading, using VOLTMETER RANGE switch to give convenient deflection.

(See Note 2 opposite)

(b) Carrier suppression

After having set carrier zero:

- ⑦ Adjust BALANCE MODULATOR controls for minimum meter reading; the controls are interacting. The degree of suppression necessary depends upon the lowest subsequent measurement frequency:

For 100 Hz suppress down to 30 dB.

For 20 Hz suppress down to 40 dB.

(c) **Meter calibration** (only necessary for absolute measurements).

- ⑧ Set FREQUENCY scale above 20 Hz.
- ⑨ Set VOLTMETER RANGE switch to CALIBRATE (fully counter-clockwise).
- ⑩ Set FUNCTION switch to CALIBRATE.
- ⑪ Adjust SET CALIBRATION control to give full scale deflection on meter (1.0 V).

(See Note 3 opposite)

2.3 MEASUREMENT PROCEDURES

The amplitude of the component frequencies of a complex waveform, within the range 20 Hz to 76 kHz, may be measured either in terms of absolute voltage or in decibels and percent relative to a fundamental datum level.

Prior to making a measurement it is necessary to carry out the calibration procedure given in Section 2.2. For full measurement accuracy with low level inputs also make sure that the analyser is not in a strong external magnetic hum field, especially when rack mounted.

In order to obtain consistent measurement accuracy an a.f.c. facility is included. When the analyser has been tuned to the signal under test the a.f.c. circuit will allow it to follow frequency variations of up to 100 Hz. This avoids the necessity for continual retuning when investigating a signal from a source that is prone to drift or where adjustments being made to the source tend to pull the output frequency.

Reading the meter

The instrument is calibrated in volts and decibels. Fig. 2.2 shows how the two attenuators are interconnected to give a relative measurement range of 10^4 V in an overall input range of 10^8 V. The meter has two voltage scales, 0 to 1.0 and 0 to 3, the reading being taken from the scale appropriate to the setting of the VOLTMETER RANGE switch, which provides the full scale multiplying factor. These two scales may also be used to obtain relative measurements in terms of percent, by reading the 0 to 1.0 scale as 0 to 100%, and the 0 to 3 scale as 0 to 30% after having set the meter reading for the fundamental to be 100% by means of the SET REFERENCE control.

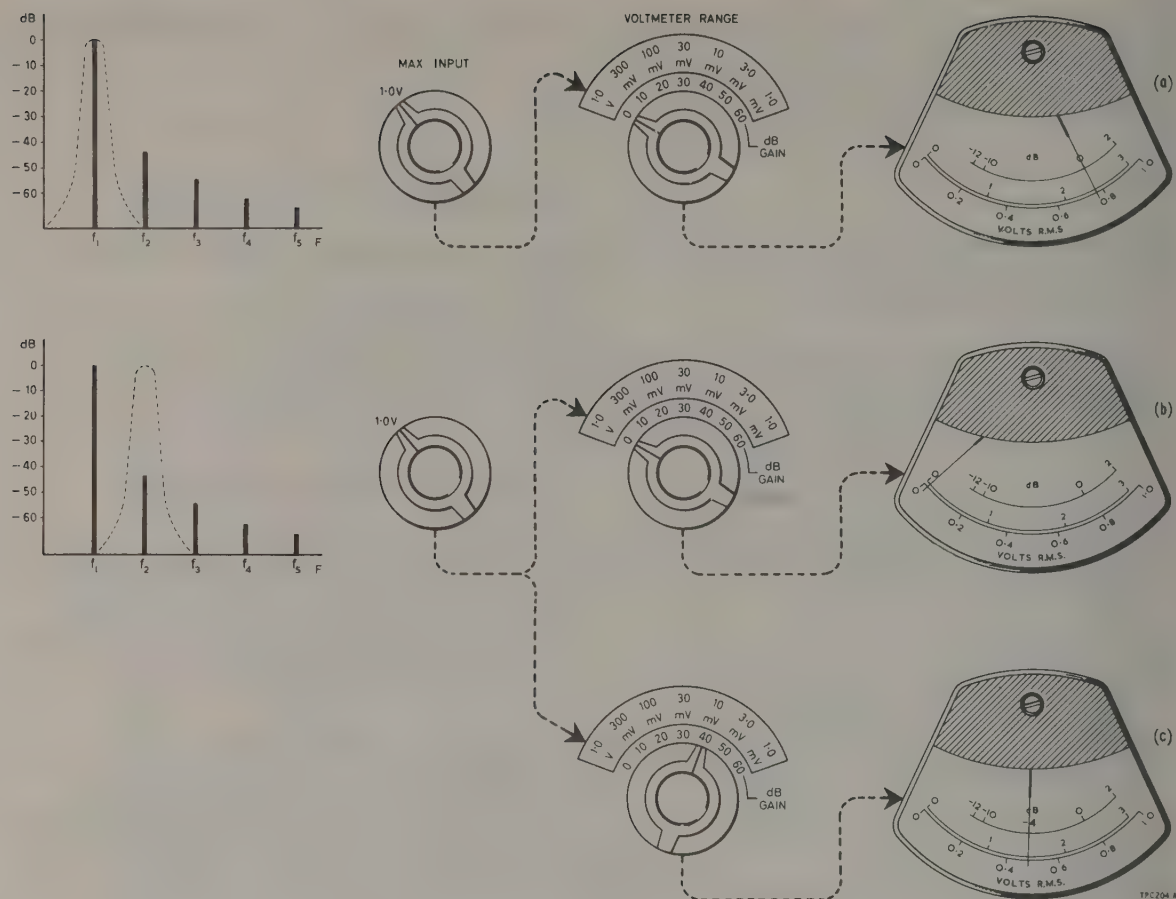


Fig. 2.2 Measurement system

Decibel calibration is in dBm, i.e. referred to 1 mW in 600 Ω , 0 dBm corresponding to 0.775 V. The meter scale covers the range -13 to +2 dB. The VOLTmeter RANGE switch, calibrated in terms of meter amplifier gain, provides a further six 10 dB steps giving a total coverage of -73 to +2 dB. To obtain a reading in dB's, subtract the VOLTmeter RANGE switch decade from the meter indication. If the fundamental amplitude has been set to 0 dB then the reading obtained will be the number of dB's the particular component is below the fundamental. The example shown in Fig. 2.2 has a second harmonic, f_2 , which is 44 dB down; however, had the meter indication been f.s.d., the resultant reading would be $2-40 = -38$ dB, i.e., 38 dB down.

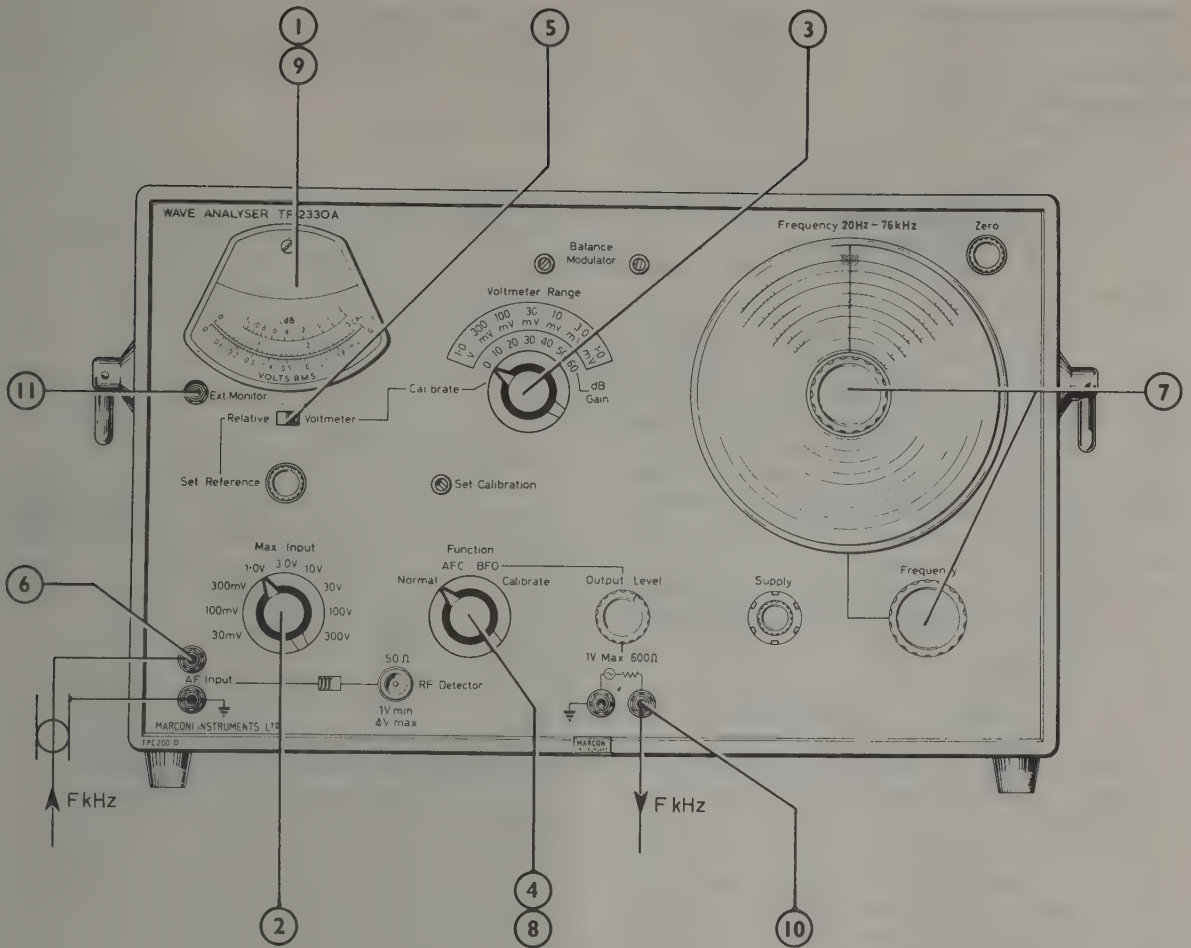
Absolute measurements

The absolute amplitude of any component of a waveform may be determined by the following

procedure. The measurement may be made in volts, or in dBm where the signal is derived from a source having a terminating impedance of 600 Ω . The difference in amplitude between individual components of a waveform from any other source may be measured in dB's by algebraically subtracting the readings obtained for each component.

A harmonic analysis of a waveform can be carried out using absolute measurements though relative measurements are usually more convenient. The procedure is simplified if the signal level can be adjusted externally for setting the fundamental datum.

- ① Calibrate instrument as detailed in Section 2.2.
- ② Set MAX INPUT switch to nearest range above expected signal level or to suitably higher range if level is unknown.



③ Set VOLTMETER RANGE switch to 0 dB (fully counter-clockwise).

④ Set FUNCTION switch to NORMAL.

⑤ Set meter slider switch to VOLTMETER.

⑥ Connect signal to INPUT terminals... Use adaptor supplied for conversion to BNC coaxial socket.

⑦ Tune for peak meter reading at signal component frequency. If meter deflection is below -10 dB set MAX INPUT switch to next lower range. When comparing several component

amplitudes set MAX INPUT switch for highest then adjust VOLTMETER RANGE to give convenient deflection for others.

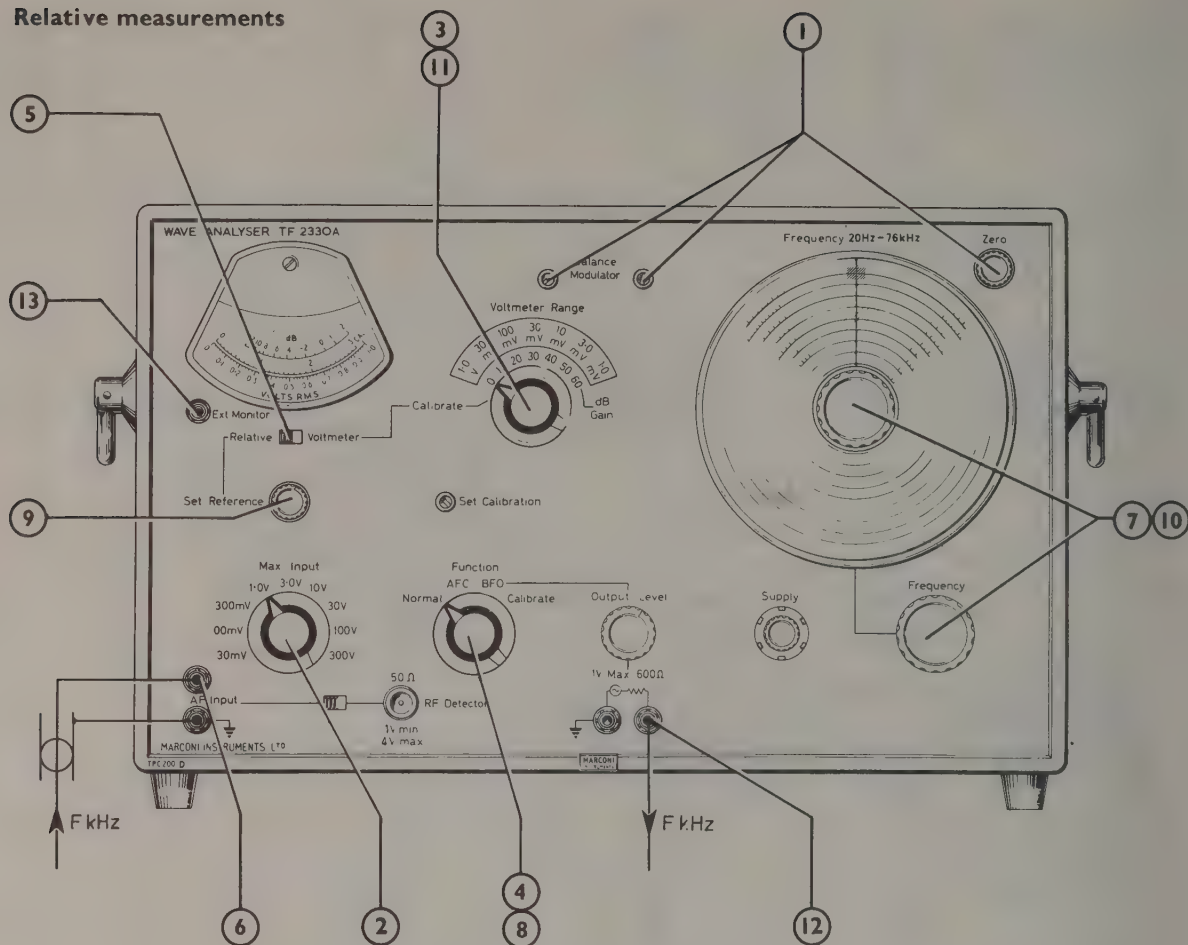
⑧ Set FUNCTION switch to A. F. C.

⑨ Read amplitude of signal component in conjunction with setting of VOLTMETER RANGE switch.

⑩ Output of up to 1 V available at frequency of component to which analyser is tuned; see Section 2.5.

⑪ External monitor may be connected in series with meter; see Section 2.5.

Relative measurements



An analysis of a waveform may be obtained by measuring the amplitudes of the harmonic and noise components relative to that of the fundamental frequency component. The measurements may be made in terms of decibels or percent.

For relative measurements the signal in the input amplifier may be adjusted by means of the SET REFERENCE control in order to set the fundamental component to a convenient datum level. Since all other measurements on the waveform are then made with reference to this datum it is not necessary for the voltmeter calibration to be absolute.

1 Carry out relevant calibration procedure as detailed in Section 2.2.

2 Set MAX INPUT switch to nearest range above expected level of fundamental or to suitably higher range if level unknown.

3 Set VOLT METER RANGE switch to 0 dB (fully counter-clockwise).

4 Set FUNCTION switch to NORMAL.

5 Set meter slider switch to RELATIVE.

6 Connect signal to INPUT terminals.

7 Tune initially for peak meter deflection at fundamental frequency.

8 Set FUNCTION switch to A. F. C.

9 Adjust SET REFERENCE control and, if necessary, MAX INPUT switch in order to set meter pointer to 0 dB or 1.0 V (100%) as required.

10 Tune to harmonic.

11 Adjust VOLT METER RANGE switch to give convenient meter deflection; DO NOT ALTER MAX INPUT SWITCH SETTING. Read harmonic amplitude from meter in conjunction with setting of VOLT METER RANGE switch.

- (12) Output of up to 1 V available at frequency of component to which the analyser is tuned; see Section 2.5.
- (13) External monitor may be connected in series with meter; see Section 2.5.

2.4 MEASUREMENTS OF MODULATION

The built-in r.f. detector stage can accommodate carrier frequencies within the range of 100 kHz to 500 MHz, modulation depths up to 80%, and levels between 1 V and 4 V. The input impedance at the R.F. DETECTOR socket is 50 Ω .

The procedure for measuring the harmonic content and hum level of an amplitude modulated signal is identical with that described in Section 2.3 except that, of course, the modulated signal is fed to the R.F. DETECTOR input and the adjacent switch is pressed towards the socket.

2.5 SIGNAL OUTPUTS

Two a.c. signal outputs are available at a pair of front panel terminals. The first is derived from the input waveform component to which the analyser is tuned, the second is generated internally to provide a useful signal source. Both outputs are developed across 600 Ω and are continuously variable up to 2.8 V p-p.

A d.c. output is available at the EXT MONITOR socket where an external recorder may be connected in series with the meter.

Restored frequency output

This output is so called because the 100 kHz i.f. signal derived from the input frequency component is recombined with the local oscillator output to provide a signal whose frequency is restored to that of the original input. The output voltage is highest at full scale deflection on the meter, and the waveform is sinusoidal but includes above 5% distortion.

When the analyser is being used to investigate a complex waveform having components that are not harmonically connected to any known fundamental the restored frequency output may be applied to an external frequency meter in order to ascertain the frequency of such a component with greater accuracy than is possible with the analyser. For this measurement the FUNCTION switch should be set to A.F.C. to ensure that the analyser is kept tuned to the component.

B.F.O. output

For this facility the output from a supplementary internal oscillator is combined with that of the local oscillator to provide a b.f.o. signal source tuned by and in step with the voltmeter tuning over the normal range of 20 Hz to 76 kHz. When the signal level has been set, using the OUTPUT LEVEL control, it will remain constant within 0.1 dB over the whole frequency range.

External monitor

The EXT MONITOR socket, situated adjacent to the meter, is connected in series with it. The d.c. flowing through the meter at any time may be used to energize a recorder so that a permanent record of an analysis can be made. The current for f.s.d. is 100 μ A into a resistance of up to 2.5 k Ω ; the recorder input must be isolated from ground and connection should be made with the jack plug provided which is a Rendar type MJP/600.

2.6 APPLICATIONS

The wave analyser is basically a highly selective and sensitive tuned voltmeter. The main application, therefore, is the measurement of individual components of a waveform whether they are harmonically related or not, for example the spurious products of modulation or noise. The ability to measure voltages as low as 3 μ V, aided by the a.f.c. facility, enables a comprehensive analysis to be made of any a.f. signal.

The other main feature is the internal b.f.o. facility which may be used as a stable energizing source of a.f. either in conjunction with the tuned voltmeter section of the instrument or on its own.

Frequency spectrum

A frequency spectrum of the output signal from an audio frequency device may be obtained by slowly tuning through the frequency range of the analyser and noting the amplitude of each frequency component of the signal. If the device under investigation is generating the output itself the results will probably be required referred to a fundamental frequency. The amplitude measurements may therefore be made either in absolute or relative terms.

If the device has to be energized from an external source, such as is the case with filters and amplifiers, it is important to ensure that no harmonics are present in the input to the device.

This is necessary because phase differences between the harmonics in the input and those introduced by the device will give rise to erroneous measurements of harmonic amplitudes. Therefore, use either a low distortion source or include a low pass filter between the source and the device.

Harmonic distortion

The distortion present in a waveform may be expressed as individual harmonics, each given as a percentage of the fundamental or as a ratio in decibels. These measurements may be made in absolute or relative terms by tuning to the fundamental and then to each successive harmonic. Remember that mains supply hum components may also be of significant proportions; if so, these should be included.

An alternative way of expressing the distortion is as a total percentage distortion factor for the waveform. This may be obtained by substituting the appropriate values in one of the following expressions.

- (a) The total percentage distortion is given by

$$D\% = \frac{\sqrt{(V_2^2 + V_3^2 + \dots + V_{H1}^2 + V_{H2}^2 + \dots)}}{V_1} \times 100$$

where V_1 is the amplitude of the fundamental.

V_2, V_3 , etc., are the amplitudes of the individual harmonic components.

V_{H1}, V_{H2} , etc., are the amplitudes of the hum components.

The values of V_1, V_2 , etc., may be absolute or relative measurements in volts or decibels.

- (b) When the amplitude of each distortion component is less than 10 to 15% a negligible error results from using

$$D\% = \sqrt{\frac{(V_2^2 + V_3^2 + \dots + V_{H1}^2 + V_{H2}^2 + \dots)}{(V_1^2 + V_2^2 + V_3^2 + \dots + V_{H1}^2 + V_{H2}^2 + \dots)}} \times 100$$

This expression gives the same value for D as would normally be obtained by a distortion factor meter.

When V_2, V_{H1} , etc., are measured as percentages of the fundamental the expression simplifies to

$$D\% = \sqrt{(V_2^2 + V_3^2 + \dots + V_{H1}^2 + V_{H2}^2 + \dots)}$$

- (c) If the distortion components levels are measured in absolute dBm or relative dB use

$$D\% = \sqrt{\left(\frac{V_2}{V_1}\right)^2 + \left(\frac{V_3}{V_1}\right)^2 + \dots + \left(\frac{V_{H1}}{V_1}\right)^2 + \left(\frac{V_{H2}}{V_1}\right)^2 + \dots} \times 100$$

where the ratios $\frac{V_2}{V_1}, \frac{V_{H1}}{V_1}$, etc., are obtained

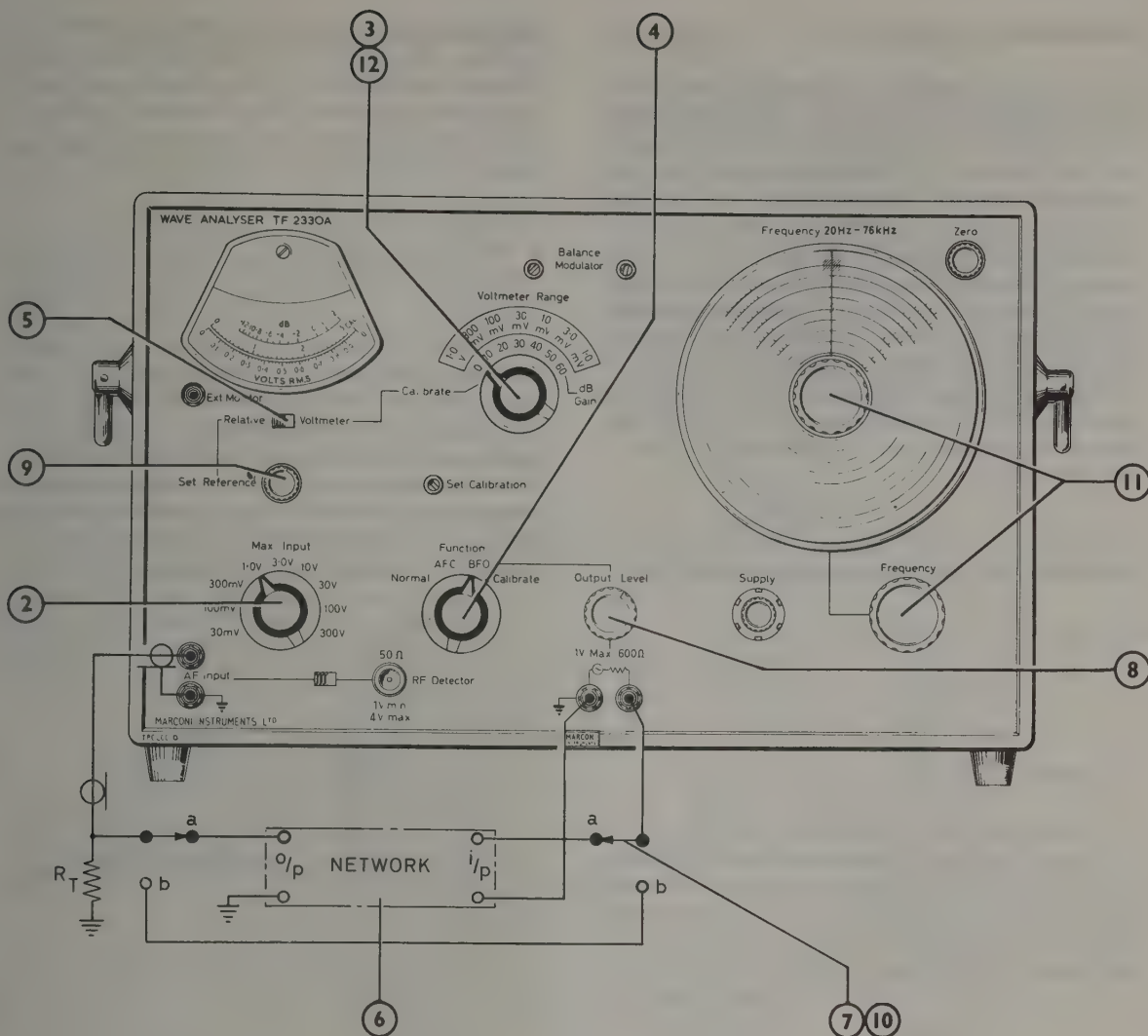
from the Decibel Conversion Table at the end of this chapter, for the number of decibels each component is down on the fundamental.

Frequency response

By using the b. f. o. output as the signal source and the tuned voltmeter as the monitor, frequency responses of networks may be easily determined over the range 20 Hz to 76 kHz. Since the b. f. o. output is derived from the internal local oscillator its frequency will automatically be in step with voltmeter tuning, also its level stability is of a similar high order.

For the response of a network such as a filter, where the required measurement is the variation in output with frequency relative to a given input, a terminating resistor, R_T , must be included. It should be equal in value to the characteristic impedance of the filter so that when setting the signal datum level the circuit impedance remains the same as when the filter is connected. For the response of an amplifier the measurement will be the variation in output with frequency relative to the output as an arbitrary centre frequency so that the network switching shown will not be required. However, the amplifier should be terminated with its normal working load.

If a test voltage of considerably less than 2.8 V p-p is required connect a potential divider between the OUTPUT terminals and the network.



① Calibrate instrument as detailed in Section 2.2.

② Set MAX INPUT switch to 1.0 V.

③ Set VOLTMETER RANGE switch to 0 dB.

④ Set FUNCTION switch to B. F. O.

⑤ Set meter slider switch to RELATIVE.

⑥ Connect network under test to B. F. O. OUTPUT and INPUT terminals. Use adaptor supplied to convert terminals to BNC coaxial socket. Value of R_T should be the same as the characteristic impedance of network. Incorporate potential divider for low test voltages.

⑦ Set NETWORK switch to 'b' position.

⑧ Adjust OUTPUT LEVEL and SET

⑨ REFERENCE controls for datum signal level (0 dB or 100% on meter).

⑩ Set Network switch to 'a' position.

⑪ Tune FREQUENCY control over required range, adjusting VOLTMETER RANGE switch to give convenient meter deflection at selected frequencies. Do not alter setting of ⑧ or ⑨.

Alternatively, when measuring frequency response of, say, an amplifier, set datum level at convenient mid-frequency (1 kHz) keeping Network switch at 'a' position.

Intermodulation distortion

Any non-linearity in an amplifier will give rise to distortion in its output. When the input to the amplifier is a simple sinewave this distortion will be in the form of harmonics and may be easily assessed by a normal harmonic analysis of the output waveform. However, when the input is a complex multi-frequency waveform certain frequency components of the waveform may interact giving rise to intermodulation distortion. Here the non-linearity causes amplitude modulation of one frequency component by another strong component. By measuring the modulation components resulting from the application of two suitable frequencies to an amplifier this distortion may be determined.

If the degree of non-linearity is uniform throughout the whole frequency range any of the

distortion measurements will give equivalent results. However, if the non-linearity is worse at one or other end of the frequency range, the appropriate intermodulation distortion measurement will give a better assessment of the non-linearity than a simple harmonic analysis.

Two methods that may be used for the measurement of intermodulation distortion in an amplifier are given below, one method giving the distortion due to non-linearity at the lower end of the frequency range, the second giving that at the upper end. In each method the two test signals are applied to the amplifier under test via an adding network, which may take the form of a centre tapped-transformer or a bridge configuration of resistors. This is to ensure that the two signals are not cross modulated before reaching the amplifier. To avoid overloading the input stages

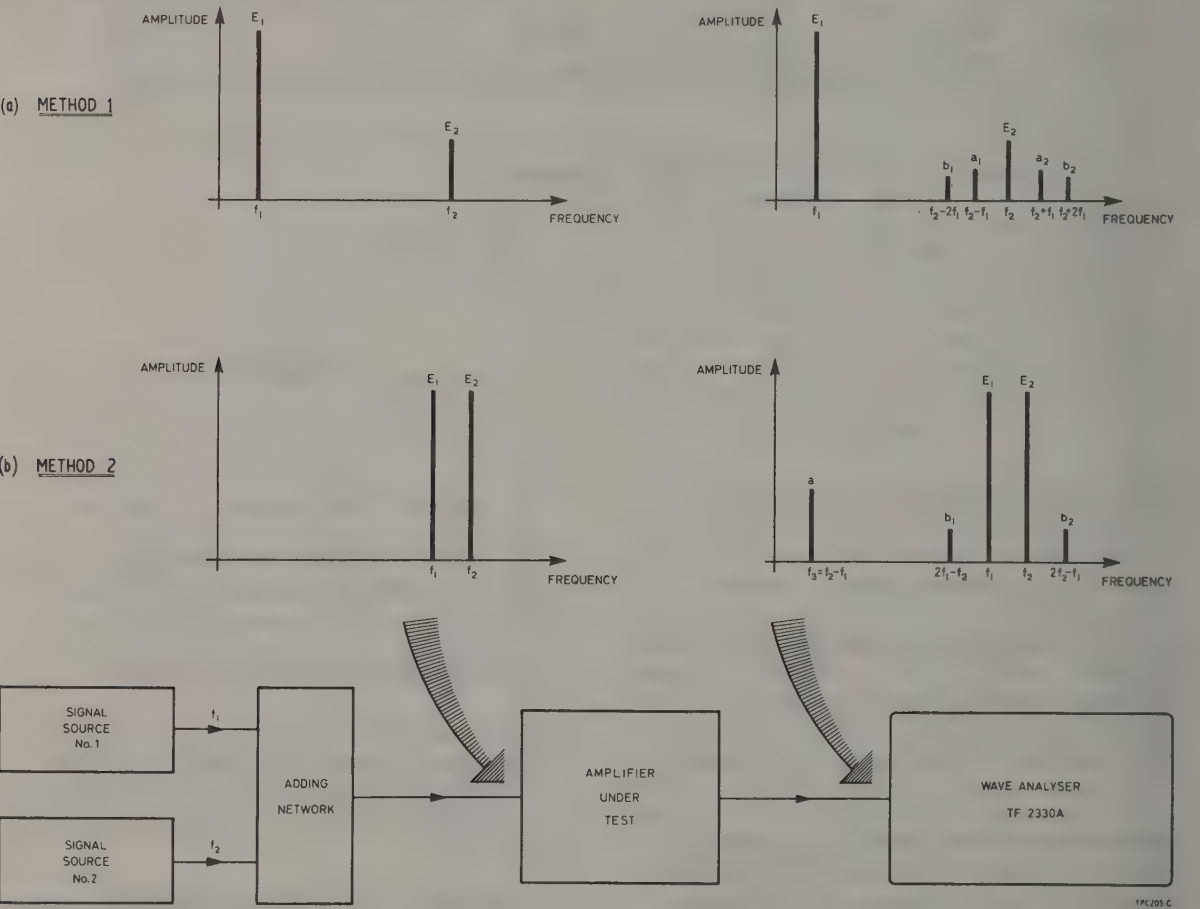


Fig. 2.3 Measurement of intermodulation distortion

the peak sum of all input signals should not exceed 1.4 x meter f. s. d.

Method 1

This method gives a measure of the distortion due to the effect of low frequencies on high frequencies, caused by non-linearity at the low frequency end.

The two test frequencies f_1 and f_2 , shown in Fig. 2.3 (a), should be chosen so that f_1 and the higher modulation components come within the bandwidth of the amplifier, otherwise the falling response at the extremes of the bandwidth will attenuate the true amplitudes of these components. The amplitude of the lower frequency, E_1 , should be four times that of the other, E_2 . The relative amplitudes of the modulation components a_1 , a_2 , b_1 , b_2 , etc., may be measured in voltage or percent, the intermodulation distortion being given by

$$\text{I. D. \%} = \frac{\sqrt{(a_1 + a_2)^2 + (b_1 + b_2)^2 + \dots}}{E_2} \times 100$$

or when E_2 is set as 100% this simplifies to

$$\text{I. D. \%} = \sqrt{(a_1 + a_2)^2 + (b_1 + b_2)^2 + \dots}$$

Method 2

This method gives a measure of low frequency distortion components produced by high frequencies due to non-linearity at the high frequency end.

The two test frequencies, f_1 and f_2 , shown in Fig. 2.3 (b), should be chosen so that they are near the upper end of the bandwidth while their difference frequency, f_3 , is near the lower end, being between 50 and 200 Hz. The amplitudes of f_1 and f_2 , E_1 and E_2 respectively, should be equal and the intermodulation distortion is given by

$$\text{I. D. \%} = \frac{a}{E_1 + E_2} \times 100$$

where a is the amplitude of f_3 .

If the levels of both E_1 and E_2 are set as 50% this simplifies to

$$\text{I. D. \%} = a.$$

The above expression gives equivalent results to those that would be obtained by using the standard measurement method of filtering out the fundamental components and measuring the second order term 'a'. This method, however, neglects the third order terms b_1 and b_2 which should also be investigated.

DECIBEL CONVERSION TABLE

Ratio Down			Ratio Up		
VOLTAGE	POWER	DECIBELS	VOLTAGE	POWER	
1.0	1.0	0	1.0	1.0	
.9886	.9772	.1	1.012	1.023	
.9772	.9550	.2	1.023	1.047	
.9661	.9333	.3	1.035	1.072	
.9550	.9120	.4	1.047	1.096	
.9441	.8913	.5	1.059	1.122	
.9333	.8710	.6	1.072	1.148	
.9226	.8511	.7	1.084	1.175	
.9120	.8318	.8	1.096	1.202	
.9016	.8128	.9	1.109	1.230	
.8913	.7943	1.0	1.122	1.259	
.8710	.7586	1.2	1.148	1.318	
.8511	.7244	1.4	1.175	1.380	
.8318	.6918	1.6	1.202	1.445	
.8128	.6607	1.8	1.230	1.514	
.7943	.6310	2.0	1.259	1.585	
.7762	.6026	2.2	1.288	1.660	
.7586	.5754	2.4	1.318	1.738	
.7413	.5495	2.6	1.349	1.820	
.7244	.5248	2.8	1.380	1.905	
.7079	.5012	3.0	1.413	1.995	
.6683	.4467	3.5	1.496	2.239	
.6310	.3981	4.0	1.585	2.512	
.5957	.3548	4.5	1.679	2.818	
.5623	.3162	5.0	1.778	3.162	
.5309	.2818	5.5	1.884	3.548	
.5012	.2512	6	1.995	3.981	
.4467	.1995	7	2.239	5.012	
.3981	.1585	8	2.512	6.310	
.3548	.1259	9	2.818	7.943	
.3162	.1000	10	3.162	10.000	
.2818	.07943	11	3.548	12.59	
.2512	.06310	12	3.981	15.85	
.2239	.05012	13	4.467	19.95	
.1995	.03981	14	5.012	25.12	
.1778	.03162	15	5.623	31.62	

DECIBEL CONVERSION TABLE (continued)

Ratio Down			Ratio Up	
VOLTAGE	POWER	DECIBELS	VOLTAGE	POWER
·1585	·02512	16	6·310	39·81
·1413	·01995	17	7·079	50·12
·1259	·01585	18	7·943	63·10
·1122	·01259	19	8·913	79·43
·1000	·01000	20	10·000	100·00
·07943	$6·310 \times 10^{-3}$	22	12·59	158·5
·06310	$3·981 \times 10^{-3}$	24	15·85	251·2
·05012	$2·512 \times 10^{-3}$	26	19·95	398·1
·03981	$1·585 \times 10^{-3}$	28	25·12	631·0
·03162	$1·000 \times 10^{-3}$	30	31·62	1,000
·02512	$6·310 \times 10^{-4}$	32	39·81	$1·585 \times 10^3$
·01995	$3·981 \times 10^{-4}$	34	50·12	$2·512 \times 10^3$
·01585	$2·512 \times 10^{-4}$	36	63·10	$3·981 \times 10^3$
·01259	$1·585 \times 10^{-4}$	38	79·43	$6·310 \times 10^3$
·01000	$1·000 \times 10^{-4}$	40	100·00	$1·000 \times 10^4$
$7·943 \times 10^{-3}$	$6·310 \times 10^{-5}$	42	125·9	$1·585 \times 10^4$
$6·310 \times 10^{-3}$	$3·981 \times 10^{-5}$	44	158·5	$2·512 \times 10^4$
$5·012 \times 10^{-3}$	$2·512 \times 10^{-5}$	46	199·5	$3·981 \times 10^4$
$3·981 \times 10^{-3}$	$1·585 \times 10^{-5}$	48	251·2	$6·310 \times 10^4$
$3·162 \times 10^{-3}$	$1·000 \times 10^{-5}$	50	316·2	$1·000 \times 10^5$
$2·512 \times 10^{-3}$	$6·310 \times 10^{-6}$	52	398·1	$1·585 \times 10^5$
$1·995 \times 10^{-3}$	$3·981 \times 10^{-6}$	54	501·2	$2·512 \times 10^5$
$1·585 \times 10^{-3}$	$2·512 \times 10^{-6}$	56	631·0	$3·981 \times 10^5$
$1·259 \times 10^{-3}$	$1·585 \times 10^{-6}$	58	794·3	$6·310 \times 10^5$
$1·000 \times 10^{-3}$	$1·000 \times 10^{-6}$	60	1,000	$1·000 \times 10^6$
$5·623 \times 10^{-4}$	$3·162 \times 10^{-7}$	65	$1·778 \times 10^3$	$3·162 \times 10^6$
$3·162 \times 10^{-4}$	$1·000 \times 10^{-7}$	70	$3·162 \times 10^3$	$1·000 \times 10^7$
$1·778 \times 10^{-4}$	$3·162 \times 10^{-8}$	75	$5·623 \times 10^3$	$3·162 \times 10^7$
$1·000 \times 10^{-4}$	$1·000 \times 10^{-8}$	80	$1·000 \times 10^4$	$1·000 \times 10^8$
$5·623 \times 10^{-5}$	$3·162 \times 10^{-9}$	85	$1·778 \times 10^4$	$3·162 \times 10^8$
$3·162 \times 10^{-5}$	$1·000 \times 10^{-9}$	90	$3·162 \times 10^4$	$1·000 \times 10^9$
$1·000 \times 10^{-5}$	$1·000 \times 10^{-10}$	100	$1·000 \times 10^5$	$1·000 \times 10^{10}$
$3·162 \times 10^{-6}$	$1·000 \times 10^{-11}$	110	$3·162 \times 10^5$	$1·000 \times 10^{11}$
$1·000 \times 10^{-6}$	$1·000 \times 10^{-12}$	120	$1·000 \times 10^6$	$1·000 \times 10^{12}$
$3·162 \times 10^{-7}$	$1·000 \times 10^{-13}$	130	$3·162 \times 10^6$	$1·000 \times 10^{13}$
$1·000 \times 10^{-7}$	$1·000 \times 10^{-14}$	140	$1·000 \times 10^7$	$1·000 \times 10^{14}$

Technical description

The following functional description should be read in conjunction with the circuit diagrams included at the end of this manual. Section 3.1 outlines the main electrical and mechanical features of the instrument while section 3.2 gives a more detailed account of the electrical circuits used therein.

3.1 GENERAL

This wave analyser is basically a super-heterodyne receiver covering the range 20 Hz to 76 kHz with an i. f. of 100 kHz. The input signal is fed via an attenuator (the MAX INPUT control) to an input amplifier. The signal then passes through a low pass filter to a ring bridge modulator. The filter stops any 100 kHz component in the input from reaching the i. f. amplifier stages.

The input signal is mixed with the output of a variable frequency local oscillator, range 100 to 176 kHz, in the ring bridge with a carrier rejection better than 80 dB. The difference frequency signal from the ring bridge is fed to the first part of a crystal filter having a 7 Hz pass band. This 100 kHz signal is then amplified and passed to the i. f. attenuator (the VOLTMETER RANGE control) which is an accurate ladder network having six 10 dB steps.

The output from the attenuator goes to the second part of the crystal filter and another amplifier stage. This is followed by the main i. f. amplifier which has adjustable gain, set by the SET CALIBRATION control.

The i. f. output is fed to the meter amplifier and rectifier circuit. A linear meter scale is

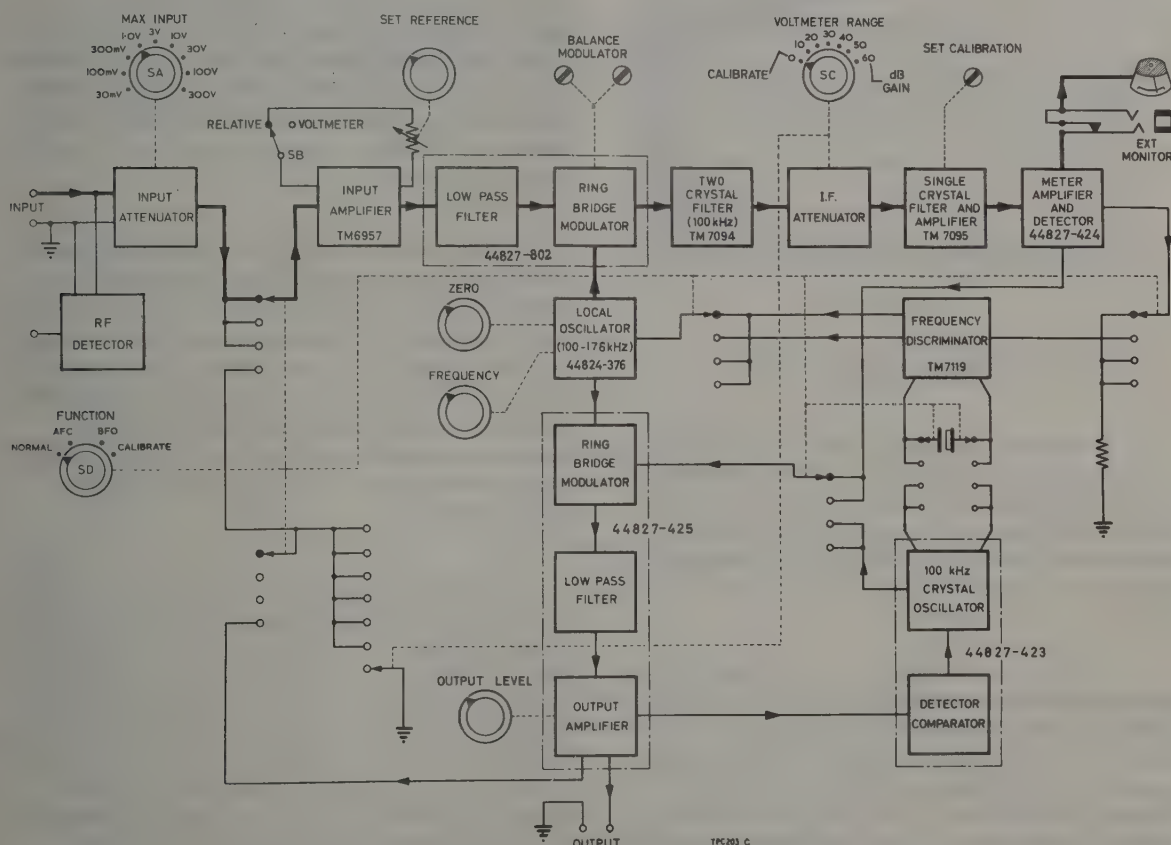


fig. 3.1 Block diagram

obtained by having the rectifier circuit in the negative feedback loop of the amplifier. A separate output from the meter amplifier is used for a.f.c. purposes and when remixed with the local oscillator output provides the restored frequency output.

Permeability tuning is used for the local oscillator with padder and trimmer inductances in the tuned circuit to enable the frequency law to be adjusted for a precalibrated frequency scale. A crystal discriminator provides the a.f.c. signal which is applied to a voltage variable capacitor included in the tuned circuit.

Modulated r.f. signals are fed to the R. F. DETECTOR socket and then demodulated by the detector, MR49. The resulting waveform is then fed into the a.f. input line via the slider switch S.G. Fig. 3.2 gives performance curves for r.f. inputs.

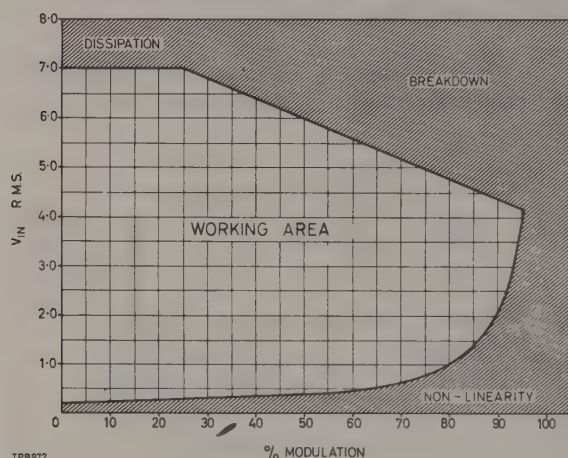


Fig. 3.2 Curve showing the working area of the r.f. detector

A restored frequency output is derived by combining the i.f. signal with the local oscillator output in another ring bridge modulator. The difference frequency, being that of the original input signal, is filtered and amplified before being fed to the output terminals via the OUTPUT LEVEL control.

A b.f.o. output is similarly derived by combining the output from a separate 100 kHz crystal oscillator with the local oscillator output. A signal taken from the output amplifier via a detector comparator provides an error signal which is added to the feedback of the 100 kHz oscillator to control its amplitude. This results in a signal of very stable output level, a feature which is utilized by also making it the calibration reference used

when setting up the gain of the voltmeter section. A relay is used to switch the reference signal to the input amplifier, located remote from the high signal levels associated with the b.f.o. circuit in order to prevent 100 kHz breakthrough. The same 100 kHz crystal is used for both the discriminator and the oscillator as the two circuits are not used simultaneously.

Power for the instrument is derived from a normal series stabilizer giving an output of 15 V. When operated on a.c. mains the output from a transformer is rectified and applied to the stabilizer, the regulation of which is such that no intermediate taps are required in the transformer primary windings for the two ranges of input voltage. Similarly, it allows a wide range of battery voltage to be used for d.c. operation.

A neat mechanical layout results from the use of ten printed circuit boards for the main circuit sections. The boards are mounted on a common chassis, five above, five below, with electrostatic screens fitted between boards where necessary. Mounted on pivots to allow limited movement for servicing accessibility, the boards are retained by easily removable screws in channels riveted to each board. Although the boards have printed plug interconnections these are only used for initial testing purposes; when they are finally assembled into the instrument soldered connections are used to avoid contact troubles.

The iron dust tuning core of the local oscillator is actuated by a precision lead screw of 10 turns per inch. The required frequency range of 100 to 176 kHz is given by a movement of 0.85 in, i.e., 8.5 turns of the tuning control. The frequency scale is an 8.5 turn spiral, the appropriate part of the scale in use being indicated by a coloured marker behind the dial. 'Add up' type stops on the control mechanism limit the lead screw travel.

In order to facilitate the determination of meter scale multiplying factor a simple mechanical computer is used to combine the functions of the two attenuators. A dial mounted on the VOLT-METER RANGE switch spindle but driven by the MAX INPUT switch is printed with the fifteen range full scale values. The dial is viewed through a window on the front panel such that only seven ranges are visible at any one time, this being the coverage of the METER RANGE switch; the selected range f.s.d. is indicated by the switch knob pointer.

3.2 CIRCUIT SUMMARY

The basic arrangement of the main circuit sections on ten printed boards also provides a convenient breakdown for the following circuit description. That section of the main circuit on any one board is shown enclosed by a broken line on the circuit diagram and each board is identified by a separate reference number.

Input Amplifier, TM 6957

The 30 mV output from the compensated input attenuator is fed to this amplifier which is a three stage feedback type having a loop voltage gain of 6. The first common emitter stage, VT50, uses a silicon p-n-p transistor for high gain with low noise and distortion. The next stage, VT51, has its base bias variable by RV51 which is set for minimum distortion. The output from this stage is fed to emitter follower VT52, with overall feedback to the emitter of VT50. Diodes MR50 and MR51 are included to protect VT50 from damage due to excessive input voltage.

For absolute measurements the overall gain is fixed, but for relative measurements a variable resistor, RV1, (the SET REFERENCE control), is switched into the emitter circuit of VT50 to give up to 10 dB of gain reduction for level setting purposes.

Low-Pass Filter and Ring Bridge Modulator, 44827- 802

The low pass filter is an m-derived network having an iterative impedance of $1000\ \Omega$. The frequency response is flat to within 0.5 dB up to 76 kHz, with attenuation at 100 kHz greater than 60 dB.

The conventional ring bridge modulator consists of MR70 to MR73, with a $1000\ \Omega$ resistor in series with each diode to swamp differences in forward resistance. The diodes are mounted on a covered B9A plug, 44529-012, thus enabling easy replacement if required, and providing a convenient point for applying a test signal for servicing purposes. Two preset potentiometers, RV2 and RV3, are mounted remote from the board on the front panel, these being the BALANCE controls which are adjusted for maximum carrier suppression.

The secondary winding of the ring bridge output transformer, T71, is tuned to 100 kHz and the output fed to the first crystal filter on TM 7094 via an emitter follower stage, VT70.

Two Crystal Filter, TM 7094

This crystal filter comprises two quartz resonators operating in the series mode and

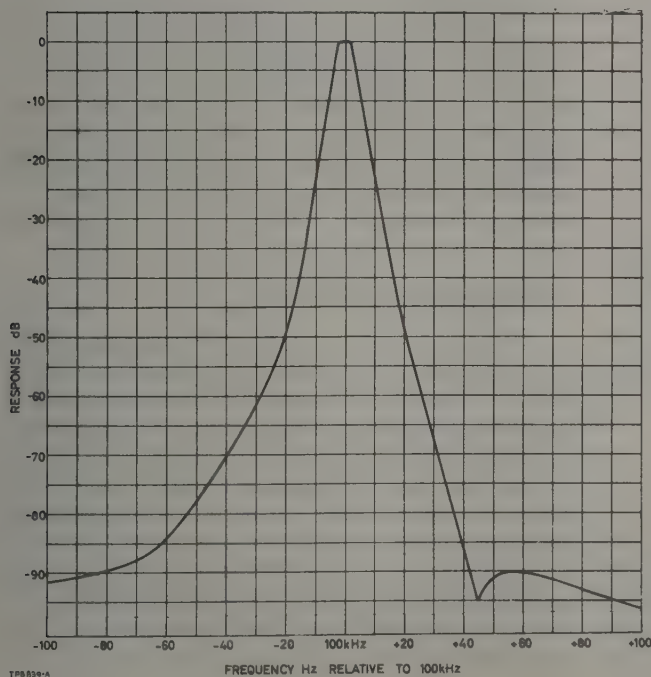


Fig. 3.3

Typical response of the crystal filters

coupled by shunt capacity. Variable resistors and capacitors connected in series with the crystals permit adjustment of Q and resonant frequency to give an overcoupled band pass characteristic. A portion of the input signal is fed past this filter section and is added to the output in such a phase as to produce nulls in the output at about 45 Hz either side of the centre frequency. This gives a double-humped response with sharp cut-off.

The filter output is fed via a common emitter stage, VT140, to the i. f. attenuator.

Single Crystal Filter and I.F. Amplifier, TM 7095

The output of the i. f. attenuator is fed to a tuned amplifier, VT160, then to a second crystal filter. This is a single quartz resonator operated in the series mode at 100 kHz. Series capacitor C165 and variable resistor RV160 are included for adjustment of resonant frequency and Q respectively. The result is a bandwidth of 7 Hz with very sharp cut-off beyond it.

The filter output is applied to a two stage feedback amplifier, VT161 and VT162, having a high input impedance and a voltage gain of approximately 150. This is followed by a further amplifier stage, VT163, which has variable gain. The SET CALIBRATION control, RV4, in the emitter circuit is used for adjusting the gain when calibrating the voltmeter.

Meter Amplifier and Rectifier, 44827-424

The meter amplifier has two stages with the meter rectifier circuit connected in the negative feedback path between the emitter of VT191 and the base of VT190. The open loop gain of the amplifier is increased by controlled positive feedback from the emitter of VT191 to the emitter of VT190. This helps to linearize the meter scale shape. Two r. f. chokes are connected in series with the meter to prevent any 100 kHz component from reaching the meter. An output, taken from the collector of VT191, is amplitude limited by diodes MR190 and MR191 and fed to the discriminator as drive for the a. f. c. circuit.

Crystal Discriminator, TM 7119

The 100 kHz input signal from the meter amplifier is amplified by VT90 and fed to the crystal discriminator. This consists of two series networks, one with a quartz resonator, the other only resistors and capacitors. The voltages across the two arms

are rectified and their difference is filtered before being fed as the a. f. c. signal to the local oscillator tuned circuit.

A second output, set by RV90, is routed via the FUNCTION switch to replace the a. f. c. signal in positions other than A. F. C. The discriminator characteristic is obtained by using both the resonant and anti-resonant frequencies of the crystal; the lower frequency peak is due to the series resonance and the upper frequency null is due to the parallel resonance (anti-resonance). The series resonant frequency is adjusted by C98 and the bandwidth by C99. C97 is made adjustable in order to equalize the outputs of the two detector circuits at the centre frequency.

100 Hz Crystal Oscillator, 44827-423

This is basically two circuits: the crystal oscillator and the amplitude control circuit. The crystal, mounted remote from the board, is also used in the a. f. c. discriminator circuit.

The crystal is used in the series resonant mode in the oscillator connected between the collector of VT210 and the base of VT211, where VT210 is in a common base configuration and VT211 is an emitter follower. Capacitor C211 is used for precise adjustment of the oscillator frequency. Positive feedback is taken from the output to the emitter of VT210 via a forward biased diode MR210, the effective resistance of which is controlled by the amplitude control circuit.

The amplitude control circuit consists of a peak detector MR213 followed by a long tailed pair, VT212 and VT213, which compares the peak amplitudes with a standard direct voltage derived from a Zener diode, MR211. In order to back off the temperature effects of the detector diode a similar diode, MR212, is connected in series with the reference voltage.

Local Oscillator, 44824-376

The oscillator circuit comprises common emitter amplifier VT110 and an emitter follower VT111. Feedback is taken via a forward biased diode MR112 and transformer T110, the amplitude of the feedback being controlled by the d. c. flowing through the diode. The tuned circuit of the oscillator is in the collector circuit of VT110, padder and trimmer inductors L112 and L113 being included to enable the frequency law to be adjusted to fit a pre-calibrated scale. Zener diode MR111 holds the collector/base voltage of VT110 constant in order to minimize frequency drift with temperature.

The voltage variable capacitor MR110 is biased by the output of the a.f.c. discriminator to lock the oscillator frequency to the input signal under test. For positions of the FUNCTION switch other than A.F.C. the discriminator provides a fixed bias for MR110.

The output from VT111 is fed to a feedback amplifier having a class B push-pull output stage using n-p-n/p-n-p transistors VT114 and VT115. The gain of this amplifier is approximately 15. A portion of the output is rectified by MR114 and compared with the voltage at the junction of R130 and R131. The resultant error voltage is used to control the current through MR112 for amplitude control as described above.

Modulator, Low-Pass Filter and Output Amplifier, 44827-425

The b.f.o. output is obtained by mixing the output of the local oscillator with that of the 100 kHz crystal oscillator in another transformer fed ring bridge. Since carrier suppression is not critical in this case no balance adjustments are included. The difference frequency is then filtered by an m-derived filter similar to that used in the voltmeter input circuit.

The output amplifier consists of three common emitter stages in cascade with overall feedback from the emitter of VT242 to the emitter of VT240. In order to facilitate direct coupling of the stages an n-p-n transistor is used for the third stage, VT242. The output, taken from potentiometer RV5 (the OUTPUT LEVEL control) in the collector circuit

of VT242, is variable up to 1 V r.m.s.; a second output, from the emitter, provides the drive for the amplitude control circuit on TM 7121.

Power Supply, TM 7116

This board consists of two sections, the rectifier and filter for the a.c. from the mains transformer and the voltage stabilizer circuit. The former is a conventional full wave rectifier using silicon diodes, MR260 and MR261. The rectified output is smoothed by a capacitor input filter comprising C260, R260 and C261.

The stabilizer input is derived either from the rectifier when operating from a.c. mains or direct from an external battery with d.c. operation. An amplifier, VT260, compares a portion of the output voltage from the series stabilizer, VT1 (mounted remote from the board), with a reference voltage derived from a Zener diode, MR262. The resultant error signal is fed via an emitter follower, VT261, to the base of the series transistor. The decoupling circuit R261 and C265 ensures that the collector supply to VT260 is free from ripple. Potentiometer RV260 is used to set up the output voltage, i.e., -15 V.

Protection for the instrument is provided by MR1, FS1, FS2 and FS3, all remote from the board. Diode MR1 prevents damage occurring due to an external d.c. supply being connected with reversed polarity. Fuses FS1 and FS2 protect the a.c. mains input and FS2 protects VT1 in the event of the stabilizer output being short circuited.

4.1 INTRODUCTION

This chapter contains information for keeping the equipment in good working order and for checking its overall performance.

Before attempting any maintenance on the wave analyser you are advised to read the preceding Technical Description chapter.

CAUTION This instrument uses semiconductor devices which, although having inherent long term reliability and mechanical ruggedness, are susceptible to damage by overloading, reversed polarity and excessive heat or radiation. Avoid hazards such as reversal of batteries, prolonged soldering, strong r.f. fields or other forms of radiation, use of insulation testers or accidentally applied short circuits. Even the leakage current from an unearthed soldering iron could cause trouble. Before shorting or breaking any circuit, refer to the circuit diagrams to establish the effect on bias arrangements of the transistor.

4.2 SCREW FASTENERS

Screw threads used on this instrument are of the following sizes: 2BA, 4BA, 6BA, 8BA.

Cruciform headed screws are of the Phillips Pozidriv pattern; to avoid damaging them a Pozidriv screwdriver should be used.

4.3 REMOVAL OF CASE

The case assembly is retained by four 2BA Pozidriv round head screws, one at each corner of the rear panel. Undo these screws and the instrument can be slid forward out of the case; alternatively, it can be placed face downwards on a soft surface and the case lifted off.

The analyser may be adapted for mounting in a standard 19 in rack. A conversion kit for this purpose, TM 8271, is available from our Service Division and fitting instructions are supplied with it.

4.4 ACCESS TO PRINTED CIRCUIT BOARDS

The printed boards are mounted in pivot blocks and are clamped to the chassis by long screws in channels at the edges of each board. The electrostatic screening plates that are mounted between some boards are held in plastic clips and clamped in the same way as the boards.

In order to make a printed board more accessible for measurement purposes, remove the clamping screws from the board and any adjacent screens and pull out the screens; the board may then be tilted over to reveal the printed wiring. For location of printed boards, see Fig. 5.2 and Fig. 5.3.

4.5 A.C. MAINS INPUT RANGES

The mains input transformer for a.c. operation has two primary windings which are connected in parallel for the 115 V range or in series for the 230 V range. The transformer is mounted in a screening can on the underside of the chassis beneath the main tuning assembly. To change the mains voltage setting reverse the L-shaped plate after setting the slide switch to its alternative position. For the range 210 V to 240 V select 230 V, for 105 V to 120 V select 115 V.

4.6 PERFORMANCE CHECKS

The tests in this section may be used as a routine maintenance procedure to verify the main performance parameters of the instrument. All tests can be completed without removing the case, except where some internal readjustment is indicated.

4.6.1 Test equipment required

Item	Type	Minimum specification	Recommended model
a	Electronic voltmeter	Range: 0.3 V to 300 V	TF 2600
b	Frequency counter	Frequency: 20 Hz to 76 kHz	TF 2411, TF 2424A
c	L. F. oscillator	Frequency: 20 Hz to 1 kHz	TF 1101, TF 2102M

4.6.2 Voltage accuracy check

Test equipment: a

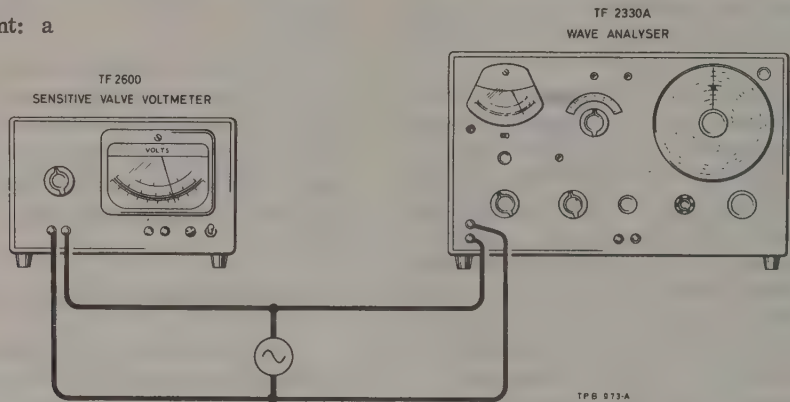


Fig. 4.1 Instruments connected for voltage accuracy check

- (1) Calibrate wave analyser as in Section 2. 2a.
- (2) Connect known a. c. voltage supply at any convenient frequency.
- (3) Monitor the a. c. voltage with an electronic voltmeter.
- (4) Set FUNCTION switch to NORMAL.
- (5) Set the meter slider to VOLTMETER.
- (6) Set the MAX INPUT switch to obtain a reading on the meter.

The method of reading the scale on the voltmeter in conjunction with the controls is detailed in Section 2. 3. With the above method a known voltage may be fed into the instrument and read off the meter. The accuracy of the reading may be checked by comparing with the reading obtained on the monitoring electronic voltmeter. It may not be possible to alter the voltage source to check the scale of the meter. In this case the MAX INPUT control can be switched in 10 dB steps to check the meter scale shape and ranges. The VOLTMETER RANGE switch may then be checked

against the MAX INPUT switch for attenuation accuracy.

4.6.3 Frequency scale accuracy check

Test equipment: b and c

- (1) Calibrate wave analyser as in Section 2. 2a.
- (2) Connect the instrument as shown.
- (3) Set FUNCTION switch to NORMAL.
- (4) Tune FREQUENCY to correspond with input frequency.

Procedure: The wave analyser is tuned to the frequencies provided by the A. F. oscillator between 20 Hz and 76 kHz. The frequency counter monitors the frequency and the scale setting can be compared with the counter reading at each tuning point.

The calibration should be carefully checked, at 5 kHz and 50 kHz in particular, and should be accurate to within $\pm 1\%$ ± 5 Hz. If this figure is not met, see Section 5. 4. 6.

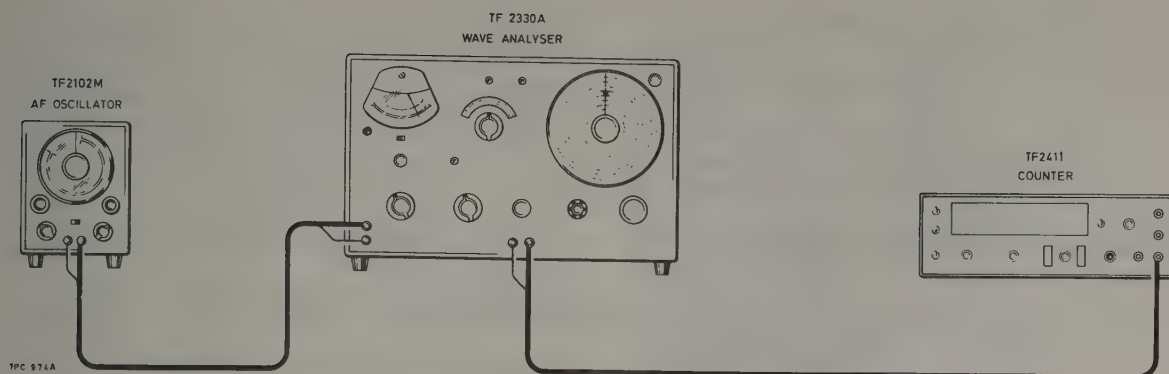


Fig. 4.2 Connections for frequency scale accuracy check

4.6.4 B.F.O. frequency accuracy check

Test equipment: b

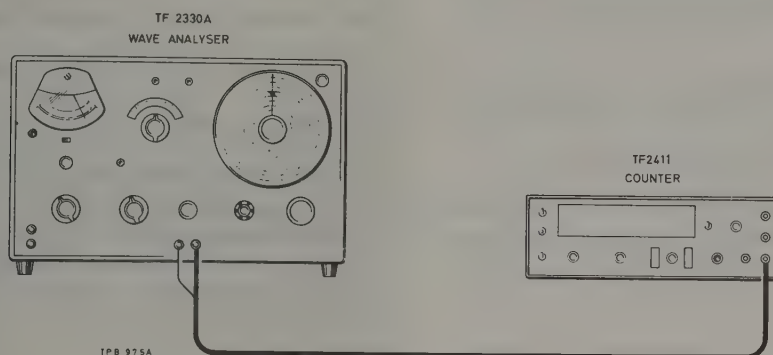


Fig. 4.3 Connections for b.f.o. frequency accuracy check

- (1) Calibrate the wave analyser as in Section 2. 2a.
 - (2) Connect the instrument as shown.
 - (3) Set FUNCTION switch to B. F. O.
 - (4) Adjust FREQUENCY between 20 Hz and 76 kHz.
- NORMAL to B. F. O. and the two readings should be equal on both the dial and the frequency counter. Also the output terminals may be linked to the INPUT terminals with a frequency counter monitoring the output. In this way, with the FUNCTION switch in the B. F. O. position, the frequency dial accuracy may be checked (providing the B. F. O. alignment is within claims, see Section 5.4. 8)

Procedure: The B. F. O. frequency is now read directly on the frequency counter, via the output terminals of the wave analyser. The reading on the counter should compare with the frequency dial reading. The accuracy should be $\pm 1\%$ ± 5 Hz. If this accuracy is not met, see Section 5.4. 8.

The B. F. O. frequency may be checked in conjunction with frequency scale accuracy (Section 4.6.3). With the test gear set up as in Section 4.6.3 the FUNCTION control may be switched from

4.6.5 B.F.O. output check

Test equipment: a

- (1) Calibrate the wave analyser as in Section 2. 2a.
- (2) Connect the instrument as shown.
- (3) Set FUNCTION switch to B. F. O.
- (4) Set the MAX INPUT switch to 1 V.

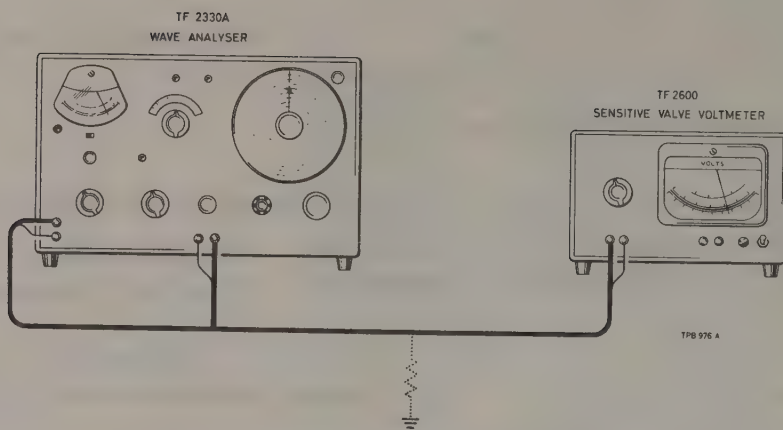


Fig. 4.4 Connections for b.f.o. output check

(5) Set the VOLTMETER RANGE switch to 1 V.

(6) Adjust OUTPUT LEVEL for f. s. d. on TF 2330 meter.

Procedure: This check may be carried out at any convenient frequency, say 1 kHz, and will reveal that the output level is within claims.

A reading will be obtained on the electronic voltmeter corresponding to the reading on the wave analyser meter. If the output is set to 1 V (f. s. d. on the meter), and terminated by 600 Ω , the output will fall to 0.5 V.

(3) Set MAX INPUT voltage switch to 3 V.

(4) Set VOLTMETER RANGE switch to 3 V.

(5) Set FUNCTION switch to NORMAL.

(6) Set the meter slider switch to RELATIVE.

The selectivity of the 2330A band-pass filter is measured by determining the filter centre frequency, the pass band characteristics and the filter rejection characteristics. Fig. 5.8 gives the pass band response and should be consulted to clarify these checks.

4.6.6 Selectivity check

Test equipment: b and c

(1) Calibrate wave analyser as in Section 2.2a.

(2) Connect instruments as shown.

Centre frequency

Set the TF 1101 and the wave analyser to 30 Hz.

Adjust the SET REFERENCE control to give 0 dB meter reading at peak tuning.

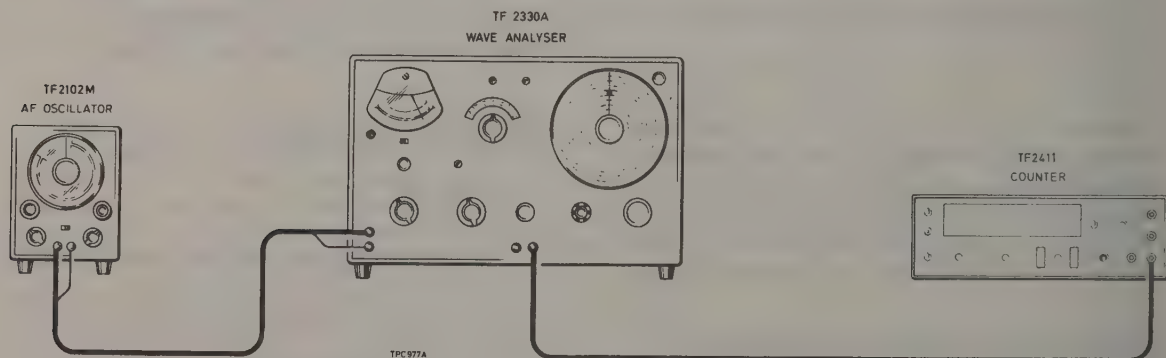


Fig. 4.5 Connections for selectivity check.

Change oscillator frequency until the meter reading drops to -3 dB each side of peak tuning point. Record both frequencies, f_a and f_b , monitored on the frequency counter. 3 dB bandwidth should not exceed 7 Hz. Compute filter centre frequency, $f_c = \frac{1}{2} (f_a + f_b)$.

Filter rejection characteristics.

Set the oscillator frequency to 200 Hz and set the wave analyser to peak at 200 Hz.

Adjust the SET REFERENCE control so that the meter reads 1.0 V.

Decrease oscillator frequency to 120 Hz.

Rejection characteristics are correct if the meter reads below 0.1 mV with the VOLTMETER RANGE switch turned fully clockwise.

Increase the oscillator frequency to 280 Hz, the meter reading should again be below 0.1 mV.

NOTE : Alignment procedures are given in Section 5.4.4.

Increase the oscillator frequency to 280 Hz, the meter reading should again be below 0.1 mV.

NOTE: Alignment procedures are given in Section 5.4.4.

4.6.7 A.F.C. discriminator check

- (1) Calibrate the wave analyser as in Section 2.2a.
- (2) Connect instruments as shown.
- (3) Set the MAX INPUT switch to 1 V.
- (4) Set the VOLTMETER RANGE switch to 1 V.

- (5) Set the FUNCTION switch to NORMAL.
- (6) Set the meter slider switch to RELATIVE.

The correct operation of the a.f.c. discrimination circuit is checked by determining the frequency hold-in range.

Set the oscillator to 300 Hz; tune the wave analyser to 300 Hz.

Adjust the SET REFERENCE control for 0.1 V on the meter.

Set the FUNCTION switch to a.f.c.

Increase the oscillator frequency slowly so that the a.f.c. circuit automatically retunes and tracks the input signal frequency. The a.f.c. circuit will eventually lose control causing a sudden drop in the meter reading. Record the counter reading at this point.

Repeat the hold-in range check by decreasing the frequency slowly, starting at 300 Hz.

Frequency hold-in range for slow input signal frequency change should be ± 100 Hz minimum.

NOTE : Alignment procedure is given in Section 5.4.5.

4.6.8 Carrier balance

This check need only be carried out when the wave analyser is being used at low frequencies.

- (a) Set the FUNCTION switch to NORMAL.
- (b) Set the FREQUENCY dial to ZERO frequency and adjust the ZERO control for a peak on the meter.

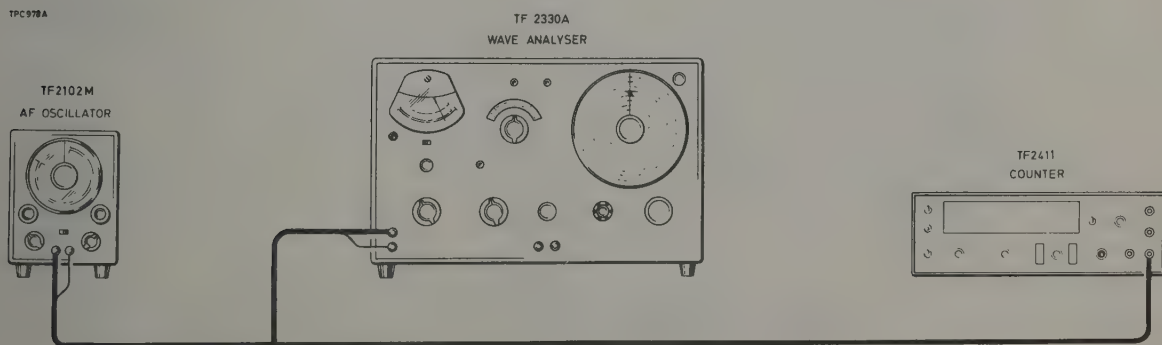


Fig. 4.6 Connections for a.f.c. discriminator check

(c) Adjust the BALANCE MODULATOR potentiometers for a minimum reading on the meter, at the same time increasing the metering sensitivity, as required, with the VOLTMETER RANGE switch.

(d) The final reading of the VOLTMETER RANGE (read off in dB) control plus the meter reading should be greater than 40 dB.

NOTE : If less than 40 dB check the Ring Bridge Modulator on board 44827-802

Alignment procedure is given in Section 5.4.7.

4.6.9 Frequency response

(a) Connect a valve voltmeter (TF 2600A) to the B.F.O. output terminals.

(b) Tune the instrument through its frequency range from 20 Hz to 76 kHz and check the frequency response in both the terminated and unterminated conditions. The frequency response should be flat to within ± 0.1 dB over the entire range.

4.6.10 Output resistance

For this check a suitable calibrated variable resistor is required, e.g. $1\ \Omega$ to $1\ \text{k}\Omega$.

(a) Set the FUNCTION switch to B.F.O.

(b) Connect the B.F.O. output to the input terminals and adjust the OUTPUT LEVEL control for f.s.d. on the meter.

(c) Connect the variable resistor in parallel

with the B.F.O. output terminals and adjust the resistor so that the meter reads half full scale. The resistance value should then be $600\ \Omega \pm 25\%$.

4.6.11 Set reference

(a) Set the FUNCTION switch to B.F.O.

(b) Set the VOLTMETER/RELATIVE switch to RELATIVE.

(c) Turn the SET REFERENCE control fully clockwise.

(d) Connect the B.F.O. output terminals to the INPUT terminals and, using the range switches and OUTPUT LEVEL control, obtain an f.s.d. reading on the meter.

(e) Turn the SET REFERENCE control fully counter clockwise and the meter should fall by at least 10 dB.

4.7 CLEANING ROTARY SWITCHES

If it is necessary to clean the contact of any rotary switches, this should be done with benzine or white spirit (not carbon tetrachloride), and the contacts should afterwards be wiped with a suitable lubricant such as a 1% solution of petroleum jelly in white spirit. Avoid lubricants containing soap or solid materials.

The chain drive from the MAX INPUT control to the VOLTMETER RANGE control may be lubricated with the above solution of petroleum jelly.

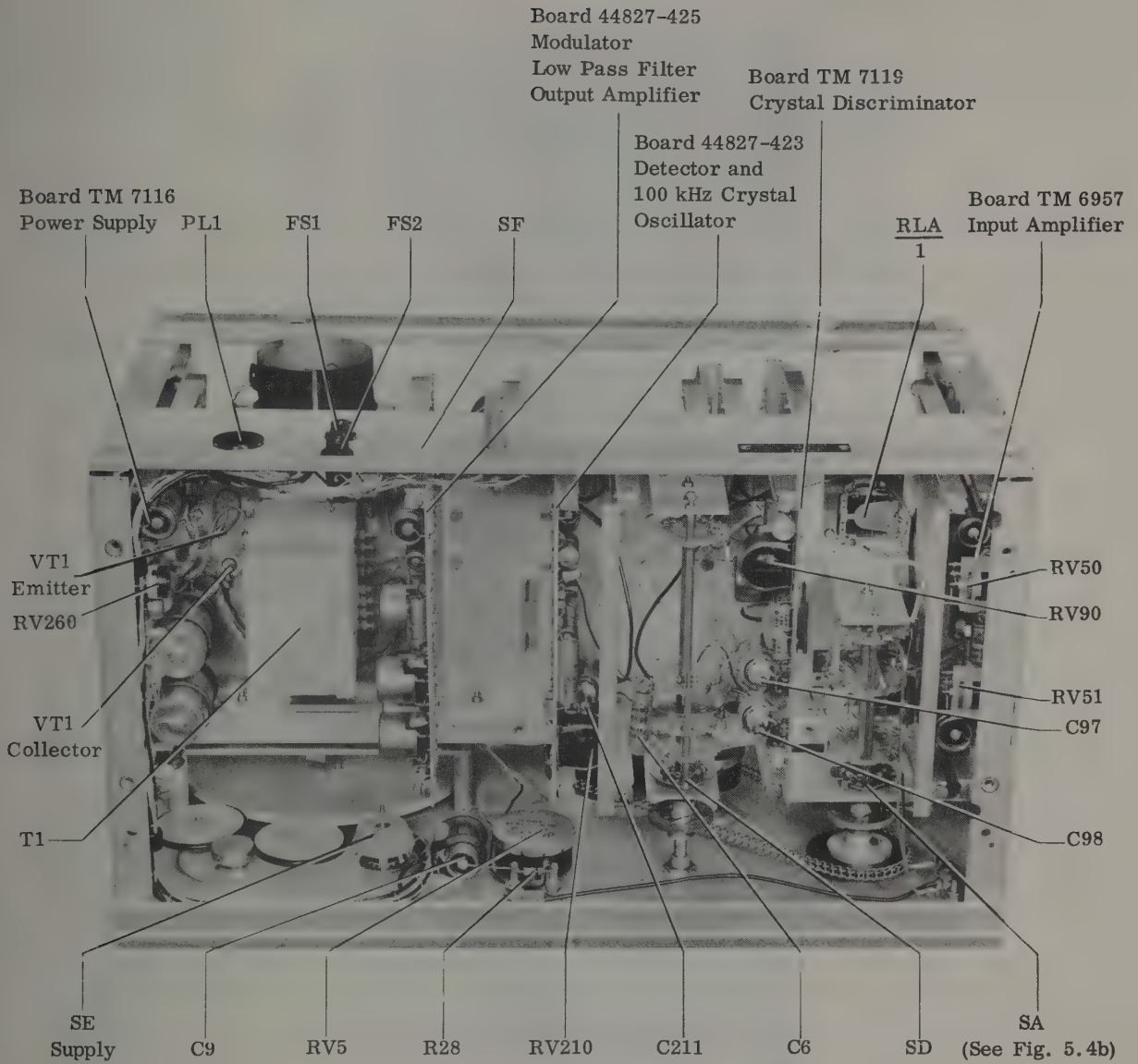


Fig. 5.3 Bottom of the instrument with screening cover removed

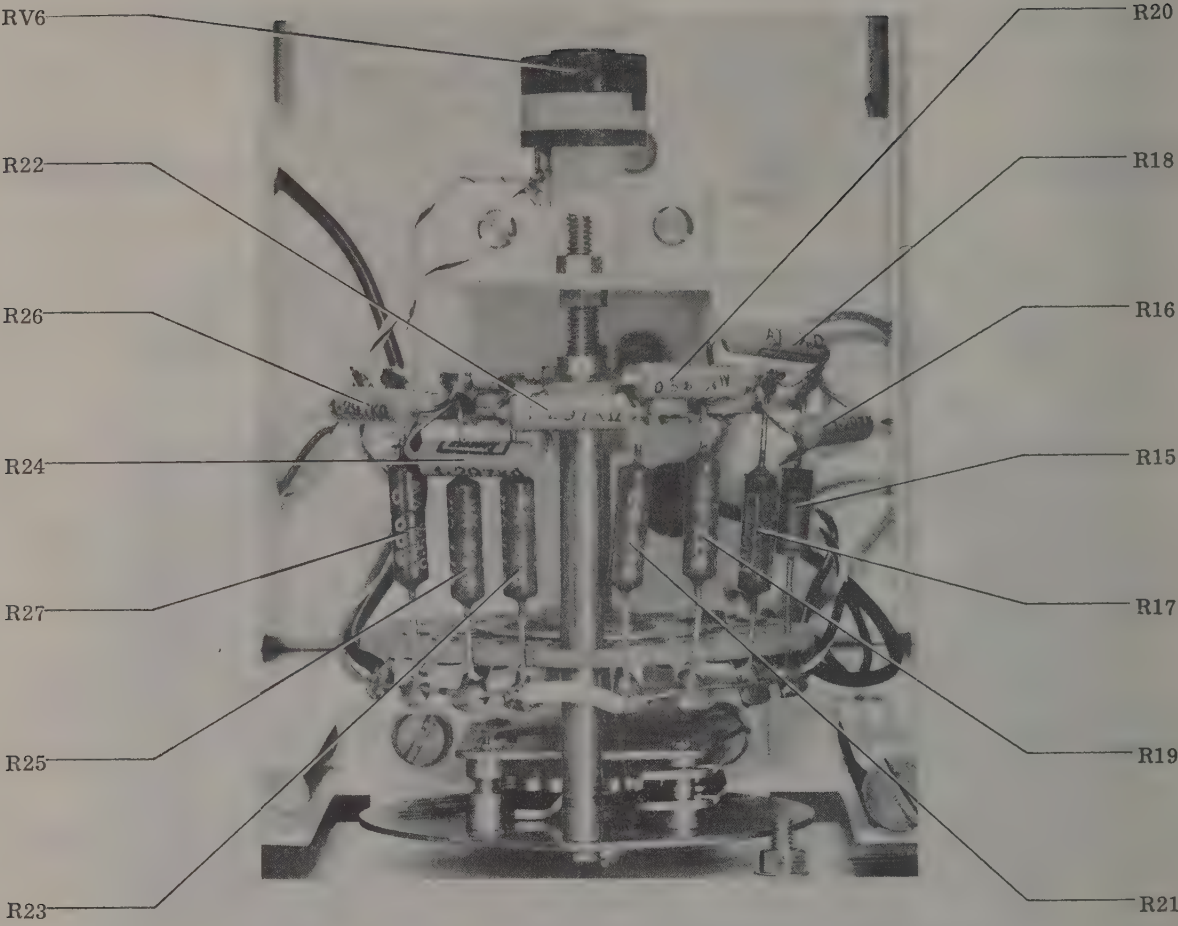


Fig. 5.4a VOLTmeter RANGE switch, SC

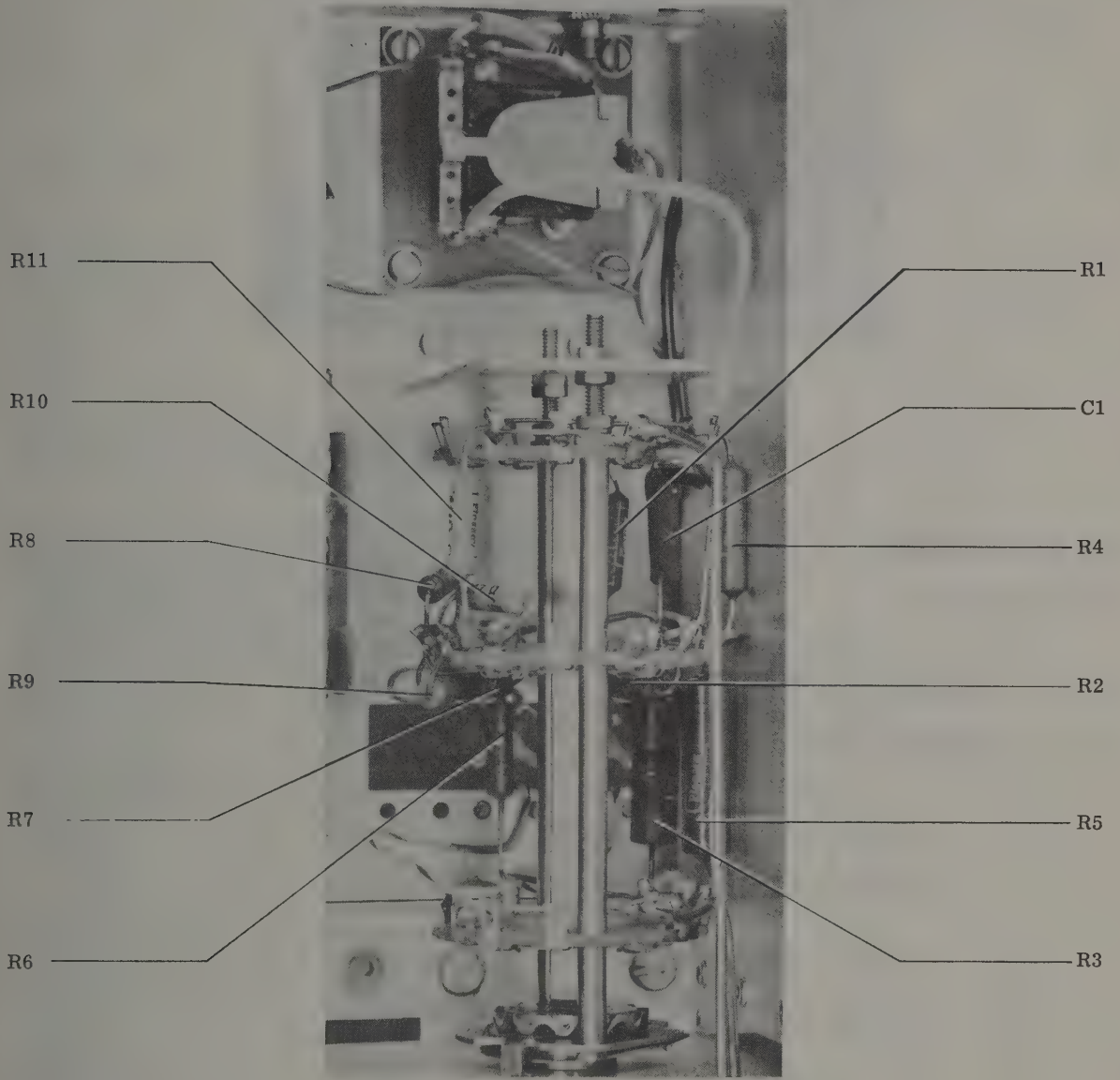
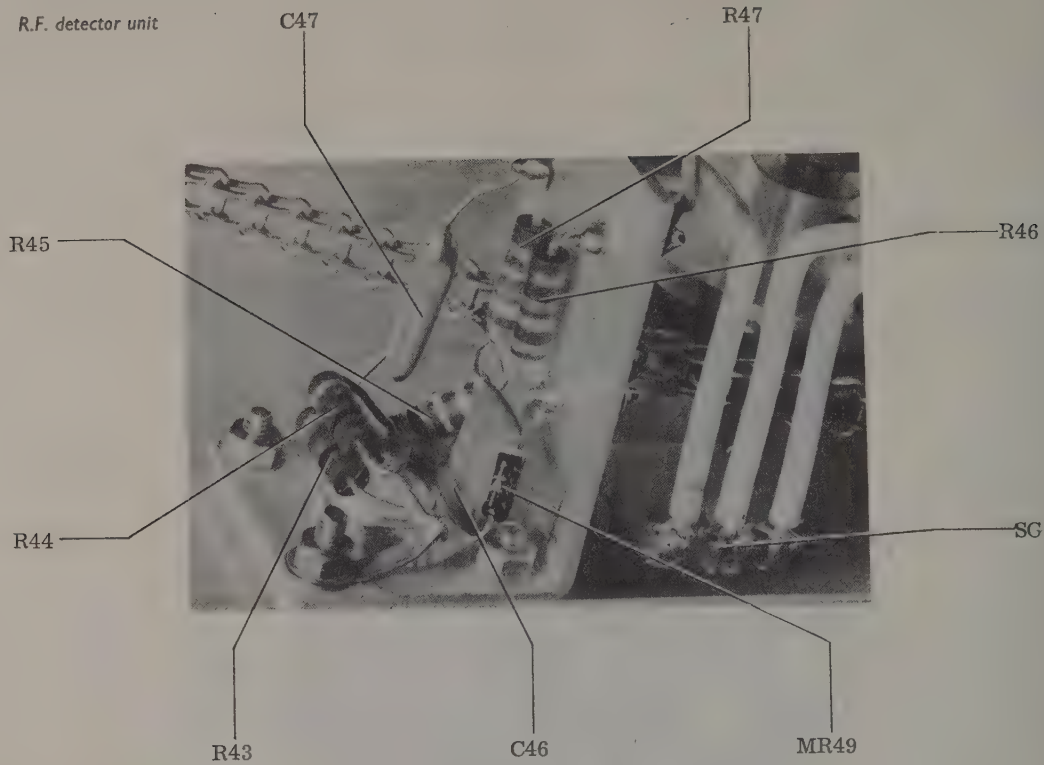


Fig. 5.4b MAX INPUT switch, SA

Fig. 5.5 R.F. detector unit



5.4 REALIGNMENT

5.4.1 Introduction

This is a complete realignment procedure with the steps arranged in a logical order. If the

full procedure is not required, for example following a component replacement, individual steps may be performed providing they do not interact with other adjustments. It is recommended that you always consider the effects of any readjustment by reference to the circuit diagrams.

5.4.2 Test equipment required

Item	Type	Minimum specification	Recommended model
a	Oscilloscope	L. F. general purpose	TF 2210, TF 2200, TF 2201.
b	Electronic voltmeter	Sensitivity 0.3 V Standardized 1%	TF 2600.
c	Frequency counter	Frequency 20 Hz to 150 kHz	TF 2411, TF 2414A
d	100 kHz oscillator	Stability: ± 1 part in 10^6 per ten minutes. 0.1 Hz discrimination.	
e	L. F. oscillator	Frequency 20 Hz to 1.5 kHz Output 0.3 V to 3 V.	TF 1101
*f	L. F. oscillator	Frequency 20 Hz to 1.5 kHz	TF 1101
g	Meter	100 μ A	
h	D. C. voltmeter	20,000 Ω /V	Avo model 8.

* The distortion check described in 5.4.11 entails the use of two L. F. oscillators.

5.4.3 Regulated power supply

Test equipment: b

- Connect the voltmeter to the emitter of VT1.
- Set the VOLTMETER RANGE switch fully clockwise.
- Set the MAX INPUT fully counter clockwise.
- Adjust RV260 to give -15 V on the voltmeter.
- Connect a lead from the h.t. rail to the input of the wave analyser.
- Set the front panel controls to provide the most sensitive range of the instrument.
- Check for h.t. ripple at 50 Hz, 100 Hz and 150 Hz. The ripple content should be less than 5 μ V.

NOTE: If excessive ripple is present the following components could be suspect: MR260, MR261, MR262, VT1, VT260 or VT261.

5.4.4 100 kHz I.F. Filters

The I. F. crystal filters consist of two units; a pair of over-coupled crystals mounted on board TM 7094 which gives the frequency response shown in Fig. 5.6, and a single crystal circuit mounted on board TM 7095 which gives the response shown in Fig. 5.7. The combination of these two filters gives the response shown in Fig. 5.8.

Since crystals are prone to aging, the crystal circuits may drift out of claims. In general, the crystal frequencies drift together but, in some cases, differential drift may cause the pass band of the crystal filter to become 'bumpy' or the A. F. C. circuit may no longer hold the signal in the centre of the pass band, or the B. F. O. may no longer lie in the centre of the i. f.

If this occurs, the procedures described below will enable the necessary adjustments to be made.

CAUTION Since the tuning of the crystal filter circuits is very critical, extreme care should be taken in carrying out these instructions.

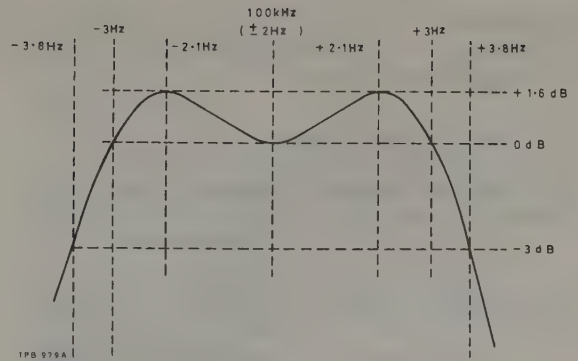


Fig. 5.6 Frequency response of crystals XL140 and XL141 on board TM 7094

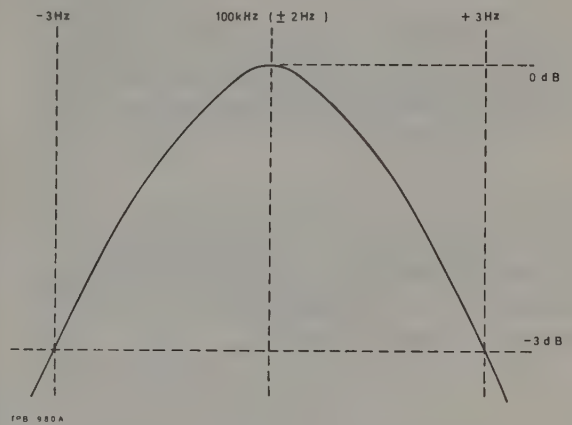


Fig. 5.7 Frequency response of crystal XL160 on board TM 7095

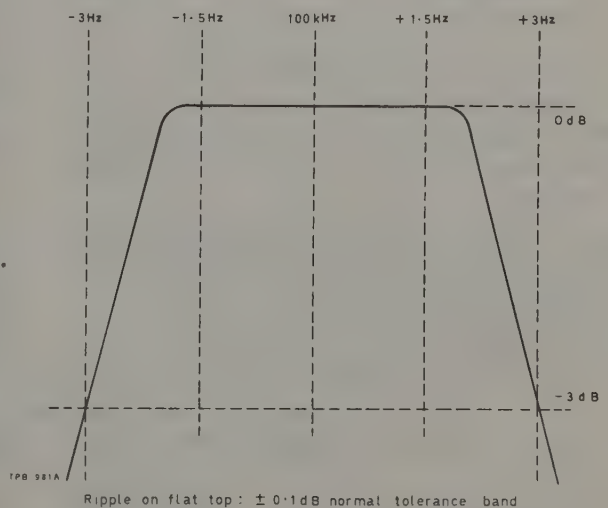


Fig. 5.8 Response waveform derived from the three crystals, XL140, XL141 and XL160

Procedure

Test equipment: c and d

1 Single crystal filter

- (a) Set the VOLTMETER RANGE switch fully counter clockwise.
- (b) Connect the 100 kHz oscillator, set to approximately 70 μ V, to pin 7 on board TM 7095.
- (c) Check the response which should be similar to that shown in Fig. 5.7.
- (d) Frequency may be adjusted using C172. (C165 may be used for coarse adjustments.)
- (e) Bandwidth may be set by adjusting RV160.

NOTE: In order to increase the bandwidth, turn RV160 so that the output increases in amplitude.

2 Two-crystal filter

- (a) Remove the ring bridge, 44529-012 (on board 44827-802) from its holder and in its place connect the 100 kc/s oscillator and a 47 Ω resistor, as shown in Fig. 5.9

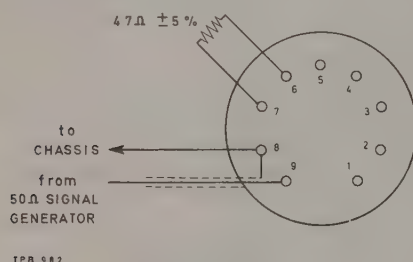


Fig. 5.9 Top view of ring bridge holder, connector B9A

- (b) Connect a 0.1 μ F capacitor between the junction of R165/XL160 and the base of VT161 on TM 7095.
- (c) With an input signal of approximately 20 mV, check the response of the filter which should be similar to that shown in Fig. 5.6.
- (d) If necessary adjust the trimmers as follows:

	Low frequency peak	High frequency peak
Frequency (fine)	C150	C151
Frequency (coarse)	C142	C146
Bandwidth	RV140	RV141

NOTE: In order to increase the bandwidth, turn RV140 so that the amplitude is reduced and RV141 so that the amplitude is increased.

- (e) Remove the 0.1 μ F capacitor.
- (f) Check the overall frequency response which should be similar to that shown in Fig. 5.8.
- (g) It may be necessary to adjust RV160 and C172 marginally to obtain the correct response.

NOTES:

- (i) Do not attempt to carry out this procedure unless a 100 kHz oscillator with adequate frequency stability and discrimination is available.
- (ii) Check the centre frequency accurately using the frequency counter. If frequency measuring equipment is not available, a standard frequency/Lissajous figure method may be used. The maximum tolerance on the centre frequency is ± 2 Hz.
- (iii) Use the meter on the instrument for reading levels and response characteristics. The 0 dB on the diagrams is for reference and not necessarily 0 dB on the meter. The oscillator level may be varied to set a convenient measuring point.
- (iv) Use non-metallic trimming tools for adjusting the capacitors.

5.4.5 Crystal discriminator alignment

Test equipment: c and e

Should the centre frequency of the crystal discriminator have drifted, the following alignment should be carried out:

- (a) Set the zero frequency of the wave analyser.
- (b) Connect the audio oscillator, set to 30 Hz, 1 V, to the INPUT.
- (c) By varying the audio frequency input explore the pass band of the instrument and set the signal to the centre frequency, i.e. midway between the 3 dB points.
- (d) Connect the frequency counter to pin 7 on board TM 7096 and note the output frequency.
- (e) Set the FUNCTION switch to A. F. C. and adjust C98 until the output frequency is the same as that noted in (d).

NOTE: If no frequency counter is available, the most practical method of setting the discriminator centre frequency is to tune in a signal for maximum meter reading, set the FUNCTION switch to A. F. C. and adjust C98 for the same reading. The main difficulty which may arise with this method is that, due to the flatness of the centre portion of the pass band, the A. F. C. may be as much as 1 Hz off tune.

5.4.6 Frequency scale alignment

Test equipment: c

CAUTION It is essential that non-magnetic or de-magnetized spanners and trimming tools are used in the following alignment procedure.

NOTE : Before proceeding, check that R64 is aligned as per Section 5.4.7.

- (a) Set the FUNCTION switch to B. F. O.
- (b) Set the ZERO control to mid-travel.
- (c) Connect the frequency counter to the B. F. O. output terminals.
- (d) Turn the FREQUENCY dial to 50 kHz.
- (e) Remove the cylindrical screening can surrounding the main tuning coil.
- (f) Adjust L112 to bring the scale calibration correct at 50 kHz as monitored on the counter.
- (g) Turn the FREQUENCY dial to 5 kHz.
- (h) Adjust L113 to bring the scale calibration correct at 5 kHz.
- (i) Adjust the insertion of the core, L1, to bring the scale calibration correct at 0 Hz (or zero).

NOTES:

- (i) Since the B. F. O. will give noise output at zero frequency it is easier to note the zero frequency as being the maximum on the meter.
- (ii) The adjustments of L112, L113 and L1 are interdependent and it will be necessary to repeat the adjustments until the frequencies are within the specification for the instrument.
- (iii) Adjustment of the core L1 should be kept to a minimum if possible.
- (iv) As very small core movements can have considerable effect on the frequency, the cores should be locked after each adjustment.

5.4.7 Carrier balance

Test equipment : a

- (a) Monitor at the junction of R76/77 or R78/79 with an oscilloscope. Tune the FREQUENCY dial to about 1 kHz and adjust R64 for a square wave of 1.1 mark/space ratio.
- (b) Set the FUNCTION switch to NORMAL and the FREQUENCY dial to zero and adjust the SET ZERO control for a peak on the meter.
- (c) Adjust the BALANCE MODULATOR presets RV2 and RV3 for a minimum meter reading increasing the VOLTMETER RANGE sensitivity as required.
- (d) When no further balance of RV2 and RV3 is possible fit wire link between Pin 16 and either Pin 17 or 18 as required to increase balance and adjust C86 for a dip. Adjust RV2 and RV3 for a further balance.
- (e) The final reading of the VOLTMETER RANGE plus the meter reading must be greater than 40 dB. Note : If still less than 40 dB check the Ring Bridge 44529-012 on board 44827-802.

5.4.8 B.F.O. alignment

Test equipment: c and e

Repeat steps (a), (b), (c) and (d) as in Section 5.4.5.

- (e) Switch to A. F. C. Note frequency. This should be the same as that noted in step d, if not, the A. F. C. discriminator requires alignment.
- (f) Switch to CALIBRATE. Note the frequency, which should be the same as in steps d and e. If not, adjust C211 on board TM 7121 until the same frequency is obtained.

NOTE: If no frequency counter is available, a Lissajous figure technique could be used. If no oscillator is available, the B. F. O. can be set approximately to the centre of the i. f. pass band by adjusting C211 until the meter reading is at the centre of the flat top of the response curve.

5.4.9 Overall frequency response

Test equipment: b

- (a) Set the FUNCTION switch to B. F. O.

(b) Connect the B.F.O. output terminals to the INPUT terminals and monitor at the B.F.O. output with the voltmeter.

(c) Set the MAX INPUT switch to 100 mV and adjust the OUTPUT LEVEL control for f.s.d. on the meter.

(d) Note the meter reading.

(e) Keeping the reading on the voltmeter constant by means of the OUTPUT LEVEL control, check the frequency response of the TF 2330 from 20 Hz to 76 kHz.

(f) Adjust C3 to give a flat response over this range.

(g) Check that the signal levels at 400 Hz and 76 kHz are within $\pm 3\%$ of each other.

(h) Set the MAX INPUT switch to 300 mV and adjust the OUTPUT LEVEL control for f.s.d. on the meter.

(i) Repeat checks (e) and (f) above.

(j) Adjust C2 to give a flat response over this range.

(k) Repeat check (h).

(l) Finally check the frequency response from 20 Hz to 76 kHz at the following positions of the MAX INPUT switch: 1 V, 3 V, 10 V, 30 V, 100 V and 300 V, adjusting the VOLTMETER RANGE switch as necessary.

(m) Repeat check (h) on each range.

5.4.10 Calibration signal level

Test equipment : b, c and e

To carry out this check a standardized 1 V, 400 Hz signal is required. The desired accuracy can be obtained by using an audio oscillator (TF 1101), and monitoring its output with a valve voltmeter (TF 2600). The distortion on the input signal should be less than 1%.

(a) Set the FUNCTION switch to NORMAL.

(b) Set the VOLTMETER/RELATIVE switch to VOLTMETER.

(c) Switch the MAX INPUT range to 1 V.

(d) Turn the VOLTMETER RANGE switch fully counter clockwise.

(e) Feed the standardized 400 Hz, 1 V signal from the signal generator to the INPUT terminals of the instrument.

(f) Tune the TF 2330A for a maximum reading on the meter.

(g) Adjust the SET CALIBRATION control to give f.s.d. on the meter.

(h) Set the FUNCTION switch to CALIBRATE.

(i) The meter should now read f.s.d., if not, adjust RV210 to obtain this.

(j) Finally, using the SET CALIBRATE and the SET REFERENCE controls, check the cover of the SET CALIBRATION control. The range coverage should be from at least +2 dB to -6 dB. If the coverage is insufficient, reset RV6 and then repeat the tests in this section.

5.4.11 External meter check

Test equipment: f

(a) Set up the TF 2330 so that the meter reads f.s.d.

(b) Plug the 100 μ A meter, with a total series resistance of 2.5 k Ω , into the EXT MONITOR socket. The internal meter reading should not change by more than 0.5%.

(c) If the change is greater than 0.5%, adjust RV190. Repeat (a) and (b).

5.4.12 Distortion check and alignment

Test equipment: e and f. Hybrid input circuit or equivalent.

Two L. F. Oscillators are required to feed in two separate frequencies to the wave analyser via the Hybrid network, see Fig. 5.10.

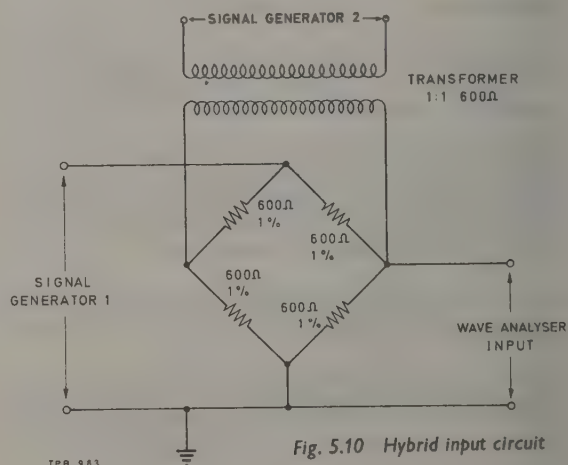


Fig. 5.10 Hybrid input circuit

The controls of the wave analyser should be set as follows:

Meter slider switch to VOLTMETER.

VOLTMETER RANGE switch to 0 dB.

MAX INPUT switch to a convenient position to suit input from oscillators.

Procedure

- (a) Set Oscillator 1 to 700 Hz.
- (b) Set Oscillator 2 to 1025 Hz.
- (c) Tune the wave analyser to peak at 700 Hz and adjust the level from oscillator 1 so that the meter reads $\frac{1}{2}$ f.s.d.
- (d) Tune the wave analyser to 1025 Hz and adjust the level from oscillator 2 so that the meter reads $\frac{1}{2}$ f.s.d.
- (e) Tune the TF 2330 to the difference frequency, i.e. 325 Hz and adjust tuning for a maximum reading.

NOTE: If there is no reading evident on the meter, the MAX INPUT control may be turned down until a reading is obtained and then returned to the original setting.

- (f) Adjust RV51 for minimum reading on the meter.
- (g) Tune the wave analyser to peak at 375 Hz.
- (h) Adjust RV51 again for a minimum reading on the meter.
- (i) Tune to 325 Hz and 375 Hz, each time adjusting RV51, until the best compromise has been obtained.
- (j) The distortion has now been adjusted to a minimum overall level.

5.4.13 Residual noise and hum

- (a) Set the FUNCTION switch to NORMAL
- (b) Set the MAX INPUT to 300 V
- (c) Turn the VOLTMETER RANGE switch to 60 dB.
- (d) Tune the instrument over its entire frequency range, 20 Hz to 76 kHz, and ensure that the meter reading is not greater than 2% of f.s.d. at any point.

NOTE: At the mains supply frequency and mains multiples the meter reading should not be greater than 6% of f.s.d. A reading greater than 2% of f.s.d. is a sure indication of a fault in the instrument. Fig. 5.11 provides an easy to follow procedure for tracing the fault by a process of elimination.

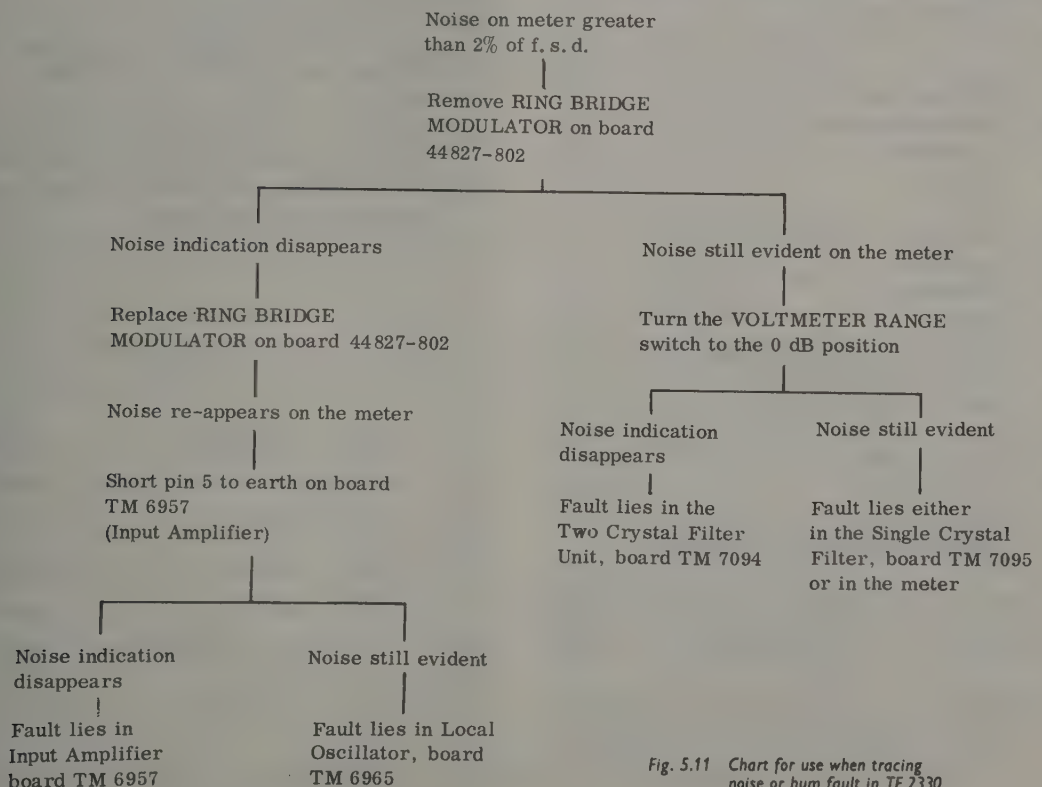


Fig. 5.11 Chart for use when tracing noise or hum fault in TF 2330

Replaceable parts

Introduction

This section lists replaceable parts in alphabetical order of their circuit references, with miscellaneous parts at the end of the list. The following abbreviations and symbols are used :

C	: capacitor
Carb	: carbon
Cer	: ceramic
CRT	: cathode ray tube
Elec	: electrolytic
FS	: fuse
JK	: jack
L	: inductor
Log	: logarithmic law
M	: meter
Met	: metal
Min	: minimum value
MR	: semiconductor diode
Ox	: oxide
PL	: plug
Plas	: plastic
R	: resistor
RV	: variable resistor
S	: switch
SKT	: socket
T	: transformer
TE	: total excursion
TH	: thermistor
TP	: terminal
V	: valve
Var	: variable
VT	: transistor
WW	: wirewound
XL	: crystal
†	: value selected during test; nominal value listed.
∅	: feed-through component
W	: watts at 70°C
W*	: watts at 55°C
W**	: watts at 40°C
W***	: watts at 20°C
W ⁰	: watts at unspecified temperature

One or more of the parts fitted to the instrument may differ from those listed in this chapter for any of the following reasons :

- (a) Components indicated by † have their value selected during test to achieve particular performance limits.

- (b) Owing to supply difficulties components may be substituted by others of different type or value provided that the overall performance of the instrument is maintained.
- (c) As part of a policy of continuous development, components may be changed in value or type to obtain detail improvements in performance.

Wherever there is such a difference between the component fitted and the one listed, always use as a replacement the same type and value as found in the instrument.

Ordering

Send your order for replacement parts to our Service Division at the address given on the back cover. Specify the following information for each part required :

- 1) Type* and serial number of instrument
- 2) Circuit reference
- 3) Description
- 4) MI code number

If a part is not listed, state its function, location and description when ordering.

- * as given on the serial number label at the rear of the instrument; if this is superseded by a model number label, quote the model number instead of the type number.

Circuit reference	Description	MI code
C1	Cer 100pF 2% 750V	26324-897
C2	Cer 8-50pF Var	26845-108
C3	Cer 8-50pF Var	26845-108
C4	Cer 3-12pF Var	26845-104
C5	Plas 220pF 2% 125V	26516-327
C6	Elec 100μF +100-20% 25V	26415-813
C7	Air 6-92.4pF Var	26812-173
C9	Elec 470μF +100-20% 25V	26415-822
C10	Cer 0.0022μF +80-20% 250V	26383-439

<i>Circuit reference</i>	<i>Description</i>	<i>M.I. code</i>	<i>Circuit reference</i>	<i>Description</i>	<i>M.I. code</i>
C46	Mica 100pF 2% 350V	26272-315	C97	Cer 3-40pF Var	26848-215
C47	Mica 100pF 2% 350V	26272-315	C98	Cer 3-40pF Var	26848-215
			C99	Cer 10-40pF Var	26847-265
C50	Elec 220 μ F +100-20% 25V	26415-818	C100	Plas 0.1 μ F 25% 350V	26174-173
C51	Plas 1 μ F 10% 400V	26512-284	C101	Elec 330 μ F 20% 6V	26486-630
C52	Elec 22 μ F +100-20% 63V	26415-806	C102	Elec 330 μ F 20% 6V	26486-630
C53	Elec 1000 μ F +100-20% 16 V	26415-825	C110	Elec 100 μ F 20% 10V	26486-606
C54	Elec 100 μ F +100-20% 25V	26415-813	C111	Plas 0.1 μ F 20% 250V	26582-208
C55	Elec 100 μ F +100-20% 25V	26415-813	C112	Mica 8140pF 0.5% 350V	26257-380
C56	Mica 1800pF 5% 200V	26268-366	C113	Cer 390pF 10% 500V	26361-924
C57	Elec 100 μ F 20% 10V	26486-606	C114	Elec 100 μ F 20% 10V	26486-606
			C115	Elec 22 μ F +100-20% 63V	26415-806
C74	Plas 200pF 2% 125V	26516-315	C116	Plas 0.01 μ F 20% 400V	26582-232
C75	Mica 4700pF 2% 200V	26268-389	C117 †	Plas 0.1 μ F 20% 250V	26582-208
C76	Cer 0.01 μ F +80-20% 100V	26383-055	C118	Plas 0.1 μ F 20% 250V	26582-208
C77	Elec 4.7 μ F 20% 35V	26486-556	C119	Plas 0.01 μ F 20% 400V	26582-232
C78	Mica 1070pF 1% 350V	26268-361	C120	Elec 100 μ F 20% 10V	26486-606
C79	Mica 1640pF 1% 200V	26268-365	C121	Plas 0.1 μ F 20% 250V	26582-208
C80	Mica 2810pF 1% 200V	26268-374	C122	Plas 0.1 μ F 20% 250V	26582-208
C81	Mica 355pF 1% 350V	26268-394	C123	Plas 0.01 μ F 20% 400V	26582-232
C82	Mica 2610pF 1% 200V	26268-372	C124	Plas 0.22 μ F 10% 400V	26555-480
C83	Mica 3410pF 1% 200V	26268-378	C125 †	Plas 360pF 2% 125V	26516-382
C84	Mica 567pF 1% 350V	26268-395	C126	Plas 10pF $\pm$ 1pF 125V	26516-009
C85 †	Plas 82pF $\pm$ 2pF 125V	26516-222	C140	Plas 0.01 μ F 20% 400V	26174-147
C86	Var air 3-17pF	26816-237	C141	Mica 33pF 5% 350V	26268-308
C87	Cer 0.01 μ F +80-20% 100V	26383-055	C142	Air 3-34pF Var	26812-314
C88	Plas 0.01 μ F 10% 250V	26582-202	C143	Mica 800pF 5% 350V	26268-356
C89	Elec 2.2 μ F 20% 20V	26486-540	C144	Plas 0.1 μ F 25% 350V	26174-173
C90	Elec 47 μ F +80-20% 25V	26417-152	C145	Mica 33pF 5% 350V	26268-308
C91	Mica 0.001 μ F 1% 350V	26268-360	C146	Air 3-34pF Var	26812-314
C92	Plas 0.1 μ F 25% 350V	26174-173	C147	Mica 0.001 μ F 1% 350V	26268-360
C93	Plas 0.1 μ F 25% 350V	26174-173	C148	Plas 0.1 μ F 25% 350V	26174-173
C94	Mica 68pF 1% 350V	26268-317	C149	Elec 5 μ F +50-20% 70V	26417-118
C95	Mica 100pF 1% 350V	26268-324	C150	Air 3-12.15pF Var	26812-311
C96	Plas 0.22 μ F 10% 400V	26555-480	C151	Air 3-12.15pF Var	26812-311

For symbols and abbreviations see introduction to this chapter

Circuit reference	Description	M.I. code	Circuit reference	Description	M.I. code
C160	Plas 0.04μF 20% 200V	26174-161	C245	Elec 100μF +100-20% 25V	26415-813
C161	Mica 0.001μF 1% 350V	26268-360	C246	Elec 100μF +100-20% 25V	26415-813
C162	Plas 0.1μF 25% 350V	26174-173	C247	Elec 100μF +100-20% 25V	26415-813
C163	Plas 0.1μF 25% 350V	26174-173	C248	Elec 470μF +100-20% 25V	26415-822
C164	Mica 33pF 5% 350V	26268-308	C249	Mica 1070pF 1% 350V	26268-361
C165	Air 3-34pF Var	26812-314	C250	Mica 1640pF 1% 200V	26268-365
C166	Plas 0.1μF 25% 350V	26174-173	C251	Mica 2810pF 1% 200V	26268-374
C167	Plas 0.22μF 10% 400V	26555-480	C252	Mica 355pF 1% 350V	26268-394
C168	Plas 0.22μF 10% 400V	26555-480	C253	Mica 2610pF 1% 200V	26268-372
C169	Elec 5μF +100-20% 15V	26414-113	C254	Mica 3410pF 1% 200V	26268-378
C170	Elec 5μF +50-20% 70V	26417-118	C255	Mica 567pF 1% 350V	26268-395
C171	Plas 0.04μF 20% 200V	26174-161			
C172	Air 3-12, 15pF Var	26812-311	C259	Elec 220μF +100-20% 25V	26415-818
			C260	Elec 500μF +100-20% 50V	26417-178
C191	Elec 5μF +100-20% 70V	26417-118	C261	Elec 500μF +100-20% 50V	26417-178
C192	Elec 5μF +100-20% 70V	26417-118	C262	Plas 0.04μF 10% 200V	26174-161
C193	Elec 5μF +100-20% 70V	26417-118	C263	Elec 50μF +100-20% 25V	26417-152
C194	Plas 0.25μF 10% 400V	26555-480	C264	Elec 1000μF +100-20% 25V	26415-826
C195	Plas 0.1μF 10% 400V	26555-475	C265	Elec 22μF +50-20% 100V	26415-807
C196	Plas 0.25μF 10% 400V	26555-480	C266 †	Plas 150pF 2% 125V	26516-287
C197	Plas 0.25μF 10% 400V	26555-480			
C198	Plas 0.1μF 25% 350V	26174-173	FS1, FS3	Delay 50mA (230V range) 100mA (115V range)	23411-051 23411-052
			FS2	Quick blow 160mA	23411-003
C210	Plas 100μF +100-20% 25V	26415-813			
C211	Cer 3-40pF Var	26848-215	JK1	Socket, 2 pole	23421-685
C212	Mica 22pF 5% 350V	26268-303			
C213	Plas 0.1μF 10% 400V	26555-475	L1	Var inductor (FREQUENCY)	44161-403
C214	Plas 0.039μF 10% 250V	26555-420			
C215	Plas 0.1μF 10% 400V	26555-475	L72	Inductor	44264-865
C216	Elec 22μF +100-20% 63V	26415-806	L73	Inductor	44266-837
C217	Elec 100μF +100-20% 6V	26415-813	L74	Inductor	44262-856
C218	Elec 5μF +100-20% 70V	26417-118			
C219	Elec 100μF +100-20% 25V	26415-813	L90	Inductor	44266-819
C220	Plas 0.022μF 10% 400V	26555-417	L91	Inductor	44263-203

For symbols and abbreviations see introduction to this chapter

Circuit reference	Description	M.I. code	Circuit reference	Description	M.I. code
L111	Inductor	44272-416	MR190	AAZ17	28322-157
L112	Var inductor	44243-204	MR191	AAZ17	28322-157
L113	Var inductor	44272-419	MR192	HG1005	28323-035
L114	Inductor	44272-416	MR193	HG1005	28323-035
L190	Inductor	44272-416	MR210	HG1005	28323-035
L191	Inductor	44272-416	MR211	Z5B 6.2	28371-483
L242	Inductor	44264-865	MR212	HG1005	28323-035
L243	Inductor	44266-837	MR213	HG1005	28323-035
L244	Inductor	44262-856	MR240	AAV30	28332-057
M1	800 Ω 100 μ A	44572-202	MR241	AAV30	28332-057
MR1	1N540	28357-048	MR242	AAV30	28332-057
MR49	1N5390	28349-005	MR243	AAV30	28332-057
MR50	1S920	28336-138	MR260	1N540	28357-048
MR51	1S920	28336-138	MR261	1N540	28357-048
MR70	MBD102	28349-004	MR262	Z5B10	28371-843
MR71	MBD102	28349-004	PL1	Mains filter	23423-150
MR72	MBD102	28349-004	RLA	430 Ω 21V	23486-123
MR73	MBD102	28349-004	R1	Met film 3300 Ω 1% $\frac{1}{4}$ W	24637-201
MR90	CG85-H	28321-201	R2	Met film 7811 Ω 1% $\frac{1}{4}$ W	24637-401
MR91	CG85-H	28321-201	R3	Met film 90k Ω 1% 1W	24667-651
MR110	SC15	28381-325	R4	Met film 46.2k Ω 1% $\frac{1}{2}$ W	24657-201
MR111	Z5B 6.2	28371-483	R5	Met film 68.37k Ω 1% 1W	24667-601
MR112	HG1005	28323-035	R6	Met film 990k Ω 1% $\frac{1}{4}$ W	24637-851
MR113	HG1005	28323-035	R7	Met film 7.840k Ω 1% $\frac{1}{4}$ W	24637-402
MR114	HG1005	28323-035	R8	Met film 2.250k Ω 1% $\frac{1}{4}$ W	24637-104
			R9	Met film 693 Ω 1% $\frac{1}{4}$ W	24636-801
			R10	Met film 217 Ω 1% $\frac{1}{4}$ W	24636-604

For symbols and abbreviations see introduction to this chapter

Circuit reference	Description	M.I. code	Circuit reference	Description	M.I. code
R11	Met film 100 Ω 1% $\frac{1}{4}$ W	24636-601	R61	Met ox 1.2k Ω 5% $\frac{1}{2}$ W	24552-082
R12	Met film 4.7k Ω 2% $\frac{1}{4}$ W	24773-289	R62	Met ox 3.3k Ω 5% $\frac{1}{2}$ W	24552-094
R15	Met ox 820 Ω 5% $\frac{1}{2}$ W	24552-078	R63	Met film 2.7k Ω 2% $\frac{1}{4}$ W	24773-283
R16	Met film 1297 Ω $\frac{1}{2}$ % $\frac{1}{4}$ W	24635-003	R64	Var cermet 4.7k Ω 10% $\frac{1}{2}$ W	25711-504
R17	Met film 877.5 Ω $\frac{1}{2}$ % $\frac{1}{4}$ W	24634-802	R65	Met film 1k Ω 2% $\frac{1}{4}$ W	24773-273
R18	Met film 1297 Ω $\frac{1}{2}$ % $\frac{1}{4}$ W	24635-003	R66	Met film 68k Ω 2% $\frac{1}{4}$ W	24773-317
R19	Met film 877.5 Ω $\frac{1}{2}$ % $\frac{1}{4}$ W	24634-802	R67	Met film 220 Ω 2% $\frac{1}{4}$ W	24773-257
R20	Met film 1297 Ω $\frac{1}{2}$ % $\frac{1}{4}$ W	24635-003	R68	Met film 9.1k Ω 2% $\frac{1}{4}$ W	24773-296
R21	Met film 877.5 Ω $\frac{1}{2}$ % $\frac{1}{4}$ W	24634-802	R69	Met film 22k Ω 2% $\frac{1}{4}$ W	24773-305
R22	Met film 1297 Ω $\frac{1}{2}$ % $\frac{1}{4}$ W	24635-003	R70	Met film 1k Ω 2% $\frac{1}{4}$ W	24773-273
R23	Met film 877.5 Ω $\frac{1}{2}$ % $\frac{1}{4}$ W	24634-802	R71	Met film 510 Ω 2% $\frac{1}{4}$ W	24773-266
R24	Met film 1297 Ω $\frac{1}{2}$ % $\frac{1}{4}$ W	24635-003	R72	Met film 750 Ω 2% $\frac{1}{4}$ W	24773-270
R25	Met film 877.5 Ω $\frac{1}{2}$ % $\frac{1}{4}$ W	24634-802	R73	Met film 430 Ω 2% $\frac{1}{4}$ W	24773-264
R26	Met film 1297 Ω $\frac{1}{2}$ % $\frac{1}{4}$ W	24635-003	R74	† Met film 820 Ω 2% $\frac{1}{4}$ W	24773-271
R27	Met film 600 Ω $\frac{1}{2}$ % $\frac{1}{4}$ W	24634-801	R75	† Met film 820 Ω 2% $\frac{1}{4}$ W	24773-271
R28	Met film 10k Ω 2% $\frac{1}{4}$ W	24773-297	R76	Met film 1k Ω 2% $\frac{1}{4}$ W	24773-273
R43	Met film 100 Ω 2% $\frac{1}{4}$ W	24773-249	R77	Met film 1k Ω 2% $\frac{1}{4}$ W	24773-273
R44	Met film 100 Ω 2% $\frac{1}{4}$ W	24773-249	R78	Met film 1k Ω 2% $\frac{1}{4}$ W	24773-273
R45	Met film 47k Ω 2% $\frac{1}{4}$ W	24773-313	R79	Met film 1k Ω 2% $\frac{1}{4}$ W	24773-273
R46	Met film 2.2M Ω 2% $\frac{1}{4}$ W	24773-974	R80	Met film 1k Ω 2% $\frac{1}{4}$ W	24773-273
R47	Met film 47k Ω 2% $\frac{1}{4}$ W	24773-313	R81	Met film 1k Ω 2% $\frac{1}{4}$ W	24773-273
R50	Met film 100 Ω 2% $\frac{1}{4}$ W	24773-249	R82	Met film 33k Ω 2% $\frac{1}{4}$ W	24773-309
R51	Met ox 10k Ω 5% $\frac{1}{2}$ W	24552-110	R83	Met film 33k Ω 2% $\frac{1}{4}$ W	24773-309
R52	Met ox 8.2k Ω 5% $\frac{1}{2}$ W	24552-108	R84	Met film 6.8k Ω 2% $\frac{1}{4}$ W	24773-293
R53	Met film 96k Ω 1% $\frac{1}{4}$ W	24637-651	R85	Met film 100 Ω 2% $\frac{1}{4}$ W	24773-249
R54	WW 3.3k Ω 5% 3 $\frac{1}{2}$ W	25125-652	R86	Met film 1k Ω 2% $\frac{1}{4}$ W	24773-273
R55	Met film 22k Ω 2% $\frac{1}{4}$ W	24773-305	R87	Met film 43k Ω 2% $\frac{1}{4}$ W	24773-312
R56	Met ox 510 Ω 5% $\frac{1}{2}$ W	24552-071	R88	Met film 51 Ω 2% $\frac{1}{4}$ W	24773-242
R57	Met film 4.7k Ω 2% $\frac{1}{4}$ W	24773-289	R90	Met film 100 Ω 2% $\frac{1}{4}$ W	24773-249
R58	Met ox 2.7k Ω 5% $\frac{1}{2}$ W	24552-092	R91	Met film 6.8k Ω 2% $\frac{1}{4}$ W	24773-293
R59	Met ox 3.9k Ω 5% $\frac{1}{2}$ W	24552-096	R92	Met film 22k Ω 2% $\frac{1}{4}$ W	24773-305
R60	Met ox 22k Ω 5% $\frac{1}{2}$ W	24552-118	R93	Met film 1.5k Ω 2% $\frac{1}{4}$ W	24773-277
			R94	Met ox 100 Ω 5% $\frac{1}{2}$ W	24552-050

For symbols and abbreviations see Introduction to this chapter

<i>Circuit reference</i>	<i>Description</i>	<i>M.I. code</i>	<i>Circuit reference</i>	<i>Description</i>	<i>M.I. code</i>
R95	Met film 2.2k Ω 2% $\frac{1}{4}$ W	24773-281	R140	Met ox 300 Ω 5% $\frac{1}{2}$ W	24552-062
R96	Met ox 6.8k Ω 5% $\frac{1}{2}$ W	24552-106	R141	Met film 27k Ω 2% $\frac{1}{4}$ W	24773-307
R97	Met ox 330 Ω 5% $\frac{1}{2}$ W	24552-063	R142	Met film 15k Ω 2% $\frac{1}{4}$ W	24773-301
R98	Met film 100k Ω 2% $\frac{1}{4}$ W	24773-321	R143	Met ox 300 Ω 5% $\frac{1}{2}$ W	24552-062
R99	Met film 100k Ω 2% $\frac{1}{4}$ W	24773-321	R144	Met film 33k Ω 2% $\frac{1}{4}$ W	24773-309
R100	Met ox 220 Ω 5% $\frac{1}{2}$ W	24552-058	R145	Met film 4.7k Ω 2% $\frac{1}{4}$ W	24773-289
R101	Met film 2.2M Ω 2% $\frac{1}{4}$ W	24773-974	R146	Met ox 180 Ω 5% $\frac{1}{2}$ W	24552-056
			R147	Met film 100 Ω 2% $\frac{1}{4}$ W	24773-249
R110	Met film 6.8k Ω 2% $\frac{1}{4}$ W	24773-293	R160	Met film 15k Ω 2% $\frac{1}{4}$ W	24773-301
R111	Met film 3.9k Ω 2% $\frac{1}{4}$ W	24773-287	R161	Met film 33k Ω 2% $\frac{1}{4}$ W	24773-309
R112	Met film 68 Ω 2% $\frac{1}{4}$ W	24773-245	R162	Met film 4.7k Ω 2% $\frac{1}{4}$ W	24773-289
R113	Met film 47k Ω 2% $\frac{1}{4}$ W	24773-313	R163	Met ox 180 Ω 5% $\frac{1}{2}$ W	24552-056
R114	Met film 15k Ω 2% $\frac{1}{4}$ W	24773-301	R164	Met film 100 Ω 2% $\frac{1}{4}$ W	24773-249
R115	Met film 470 Ω 2% $\frac{1}{4}$ W	24773-265	R165	Met ox 820 Ω 5% $\frac{1}{2}$ W	24552-078
R116	Met film 820 Ω 2% $\frac{1}{4}$ W	24773-271	R166	Met film 6.8k Ω 2% $\frac{1}{4}$ W	24773-293
R117	Met film 820 Ω 2% $\frac{1}{4}$ W	24773-271	R167	Met ox 1k Ω 5% $\frac{1}{2}$ W	24552-080
R118	Met film 4.7k Ω 2% $\frac{1}{4}$ W	24773-289	R168	Met film 33k Ω 2% $\frac{1}{4}$ W	24773-309
R119	Met ox 2.2k Ω 5% $\frac{1}{2}$ W	24552-088	R169	Met film 2.2k Ω 2% $\frac{1}{4}$ W	24773-281
R120	Met ox 33k Ω 5% $\frac{1}{2}$ W	24552-122	R170	Met ox 180 Ω 5% $\frac{1}{2}$ W	24552-056
R121	Met ox 9.1k Ω 5% $\frac{1}{2}$ W	24552-109	R171	Met film 8.2k Ω 2% $\frac{1}{4}$ W	24773-295
R122	Met film 2.2k Ω 2% $\frac{1}{4}$ W	24773-281	R172	Met ox 27k Ω 5% $\frac{1}{2}$ W	24552-120
R123	Met film 3.3k Ω 2% $\frac{1}{4}$ W	24773-285	R173	Met film 6.8k Ω 2% $\frac{1}{4}$ W	24773-293
R124	Met ox 560 Ω 5% $\frac{1}{2}$ W	24552-072	R174	Met film 3.3k Ω 2% $\frac{1}{4}$ W	24773-285
R125	Met film 4.7k Ω 2% $\frac{1}{4}$ W	24773-289	R175	Met film 10k Ω 2% $\frac{1}{4}$ W	24773-297
R126	Met film 10 Ω 2% $\frac{1}{4}$ W	24773-225	R176	Met film 33k Ω 2% $\frac{1}{4}$ W	24773-309
R127	Met film 10 Ω 2% $\frac{1}{4}$ W	24773-225	R177	Met film 2.2k Ω 2% $\frac{1}{4}$ W	24773-281
R128	Met ox 150 Ω 5% $\frac{1}{2}$ W	24552-054	R178	Met film 100 Ω 2% $\frac{1}{4}$ W	24773-249
R129	Met ox 1k Ω 5% $\frac{1}{2}$ W	24552-080	R179	Met film 4.7k Ω 2% $\frac{1}{4}$ W	24773-289
R130	Met ox 2.2k Ω 5% $\frac{1}{2}$ W	24552-088			
R131	Met film 330 Ω 2% $\frac{1}{4}$ W	24773-261	R190	Met ox 5.6k Ω 2% $\frac{1}{2}$ W	24573-091
R132	Met ox 10k Ω 5% $\frac{1}{2}$ W	24552-110	R191	Met ox 33k Ω 2% $\frac{1}{2}$ W	24573-109
R133	Met film 39k Ω 2% $\frac{1}{4}$ W	24773-311	R192	Met film 100 Ω 2% $\frac{1}{4}$ W	24773-249
R134	Met film 100 Ω 2% $\frac{1}{4}$ W	24773-249	R193	Met ox 5.6 Ω 5% $\frac{1}{2}$ W	24552-014
R135 †	Met film 680 Ω 2% $\frac{1}{4}$ W	24773-269			

For symbols and abbreviations see introduction to this chapter

Circuit reference	Description	M.I. code	Circuit reference	Description	M.I. code
R194	Met film 1.8k Ω 2% $\frac{1}{4}$ W	24773-279	R248	Met film 180 Ω 2% $\frac{1}{4}$ W	24773-055
R195	Met film 8.2k Ω 2% $\frac{1}{4}$ W	24773-295	R249	Met film 10k Ω 2% $\frac{1}{4}$ W	24773-097
R196	Met film 2.7k Ω 2% $\frac{1}{4}$ W	24773-283	R250	Met film 4.7k Ω 2% $\frac{1}{4}$ W	24773-089
R197	Met ox 270 Ω 2% $\frac{1}{2}$ W	24573-059	R251	Met film 2.2k Ω 2% $\frac{1}{4}$ W	24773-281
R198	Met film 1.2k Ω 2% $\frac{1}{4}$ W	24773-275	R252	Met ox 22k Ω 2% $\frac{1}{2}$ W	24573-105
R199	Met film 1.5k Ω 2% $\frac{1}{4}$ W	24773-277	R253	Met ox 470 Ω 2% $\frac{1}{2}$ W	24573-065
R200	Met film 100k Ω 2% $\frac{1}{4}$ W	24773-321	R254	Met film 1.5k Ω 2% $\frac{1}{4}$ W	24773-077
R210	Met film 470 Ω 2% $\frac{1}{4}$ W	24773-265			
R211	Met film 27k Ω 2% $\frac{1}{4}$ W	24773-307	R260	WW 10 Ω 5% 1 $\frac{1}{2}$ W	25123-020
R212	Met film 2.2k Ω 2% $\frac{1}{4}$ W	24773-281	R261	Met film 10k Ω 2% $\frac{1}{4}$ W	24773-297
R213	Met film 5.6k Ω 2% $\frac{1}{4}$ W	24773-291	R262	Met film 10k Ω 2% $\frac{1}{4}$ W	24773-297
R214	Met film 820 Ω 2% $\frac{1}{4}$ W	24773-271	R263	Met film 3.9k Ω 2% $\frac{1}{4}$ W	24773-287
R215	Met film 22k Ω 2% $\frac{1}{4}$ W	24773-305	R264	Met ox 3.9k Ω 5% $\frac{1}{2}$ W	24552-096
R216	Met film 22k Ω 2% $\frac{1}{4}$ W	24773-305	R265	Met ox 1.8k Ω 5% $\frac{1}{2}$ W	24552-086
R217	Met film 6.8k Ω 2% $\frac{1}{4}$ W	24773-293	R266	Met film 4.7k Ω 2% $\frac{1}{4}$ W	24773-289
R218	Met film 1k Ω 2% $\frac{1}{4}$ W	24773-273			
R219	Met film 10k Ω 2% $\frac{1}{4}$ W	24773-297	RV1	WW 2.5k Ω 10% 1W ^o	25853-127
R220	Met film 3.3k Ω 2% $\frac{1}{4}$ W	24773-285	RV2	WW 500 Ω 10% 3W ^o	25823-408
R221	Met ox 3.9k Ω 2% $\frac{1}{2}$ W	24573-087	RV3	WW 500 Ω 10% 3W ^o	25823-408
R222	Met ox 680 Ω 2% $\frac{1}{2}$ W	24573-069	RV4	WW 1k Ω 10% 1W ^o	25815-315
R223	Met film 22k Ω 2% $\frac{1}{4}$ W	24773-305	RV5	WW 600 Ω 10% 1W ^o	25815-307
R224	Met film 18k Ω 2% $\frac{1}{4}$ W	24773-303	RV6	Carb 10k Ω 20% $\frac{1}{4}$ W ^o	25611-213
			RV50	Carb 15k Ω 20% $\frac{1}{4}$ W	25611-128
R226	Met film 22k Ω 2% $\frac{1}{4}$ W	24773-305	RV51	Carb 4.7k Ω 20% $\frac{1}{4}$ W	25611-122
R227	Met film 1k Ω 2% $\frac{1}{4}$ W	24773-273	RV90	WW 1k Ω 10% 1W ^o	25811-538
R228	Met ox 10k Ω 2% $\frac{1}{2}$ W	24573-097			
			RV140	WW 1.5k Ω 10% 1W ^o	25811-542
R240	Met film 1k Ω 2% $\frac{1}{4}$ W	24773-073	RV141	WW 1.5k Ω 10% 1W ^o	25811-542
R241	Met film 1k Ω 2% $\frac{1}{4}$ W	24773-073	RV160	WW 1.5k Ω 10% 1W ^o	25811-542
R242	Met film 220 Ω 2% $\frac{1}{4}$ W	24773-057			
R243	Met film 220 Ω 2% $\frac{1}{4}$ W	24773-057	RV190	Carb 470 Ω 20% $\frac{1}{4}$ W ^o	25611-170
R244	Met film 4.7k Ω 2% $\frac{1}{4}$ W	24773-089	RV191	Carb 1k Ω 20% $\frac{1}{4}$ W ^o	25611-172
R245	Met ox 12k Ω 2% $\frac{1}{2}$ W	24573-099	RV210	WW 1k Ω 10% 1W ^o	25811-538
R246	Met film 100 Ω 2% $\frac{1}{4}$ W	24773-249	RV260	Carb 1k Ω 20% $\frac{1}{4}$ W	25611-114
R247	Met film 3.3k Ω 2% $\frac{1}{4}$ W	24773-085			

For symbols and abbreviations see introduction to this chapter

Circuit reference	Description	M.I. code	Circuit reference	Description	M.I. code
SA	MAX INPUT	44325-802	VT90	BCY72M	28433-487
SB	VOLTMETER/RELATIVE	23467-161	VT110	BCY72M	28433-487
SC	VOLTMETER RANGE	44325-107	VT111	BCY72M	28433-487
SD	FUNCTION	44323-704	VT112	BCY72M	28433-487
SE	SUPPLY	44340-102	VT113	2N404	28423-508
SF	BATTERY/MAINS	23467-161	VT114	2N1304	28443-528
SG	RF DETECTOR	23467-161	VT115	2N404	28423-508
SH	Voltage range	23467-161			
SKT 1	50Ω N TYPE	23443-733	VT140	BCY72M	28433-487
			VT160	BCY72M	28433-487
			VT161	2N404	28423-508
T1	Mains	43453-006	VT162	2N404	28423-508
T70	Modulator	43590-043	VT163	2N404	28423-508
T71	Modulator	44264-009	VT190	BCY72M	28433-487
T110	Coupling	44268-416	VT191	2N404	28423-508
			VT210	2N1304	28443-528
T140	IF 100kHz	44266-820	VT211	2N404	28423-508
T160	IF 100 kHz	44266-820	VT212	BCY33	28434-217
T240	Modulator	44267-402	VT213	BCY33	28434-217
T241	Modulator	44267-402			
			VT240	2N404	28423-508
TP1	Test point	23421-086	VT241	2N404	28423-508
			VT242	2N1304	28443-528
VT1	0C25	28424-807	VT260	2N404	28423-508
VT50	NKT0007	28432-184	VT261	ACY17	28426-497
VT51	NKT0007	28432-184			
VT52	2N404	28423-508	XL90	Specially selected set of four crystals Type Salford JC/QC 855	44524-305
VT70	2N404	28423-508	XL140		
VT71	BSX20	28452-197	XL141		
VT72	BSX20	28452-197	XL160		

For symbols and abbreviations see introduction to this chapter

Circuit diagrams

Circuit notes

1. COMPONENT VALUES

Resistors: No suffix = ohms, k = kilohms, M = megohms.

Capacitors: No suffix = microfarads, p = picofarads.

† value selected during test, nominal value shown.

2. SYMBOLS

-  arrow indicates clockwise rotation of knob.
etc., external front or rear panel marking.
-  FUNCTION
-  tag on printed board.
-  other tag.
-  preset control.
-  printed board designation.
-  test point.
-  main signal path.
-  control or modulation path.
-  point marked with this symbol is connected to a similarly marked point.

3. VOLTAGES

Shown in *italics* adjacent to point to which the measurement refers. DC relative to chassis unless otherwise stated.

4. SWITCHES

Rotary switches are drawn schematically.

The sections are identified

1st section, front: 1F

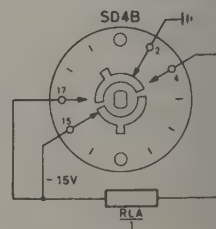
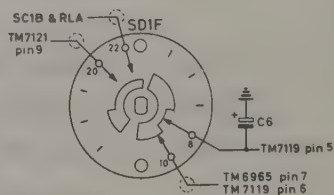
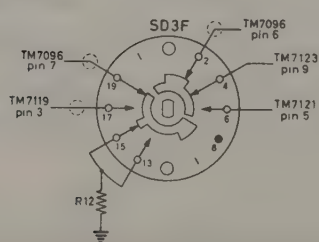
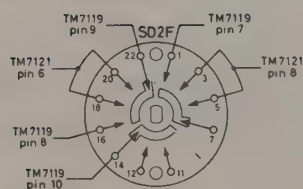
1st section, back: 1R

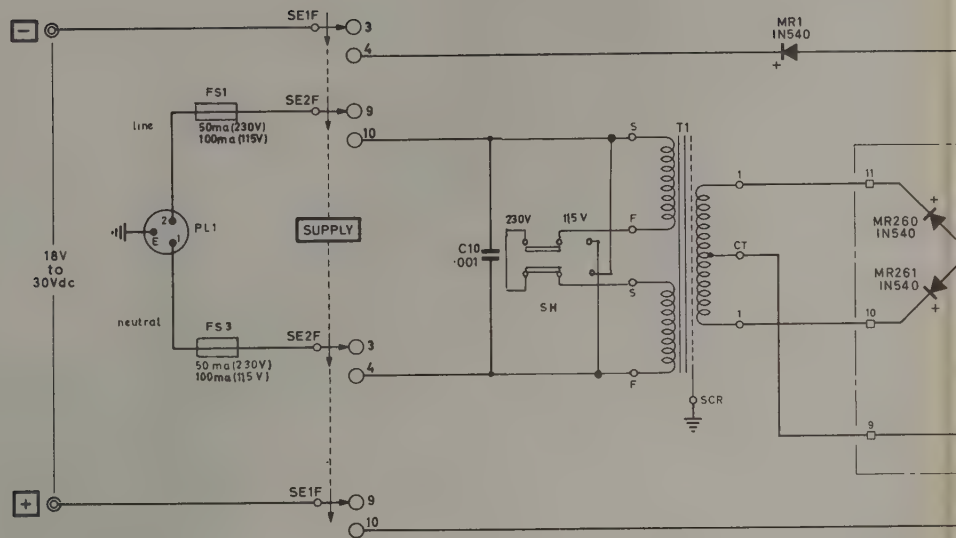
2nd section, front: 2F

2nd section, back: 2R

etc

switch diagrams





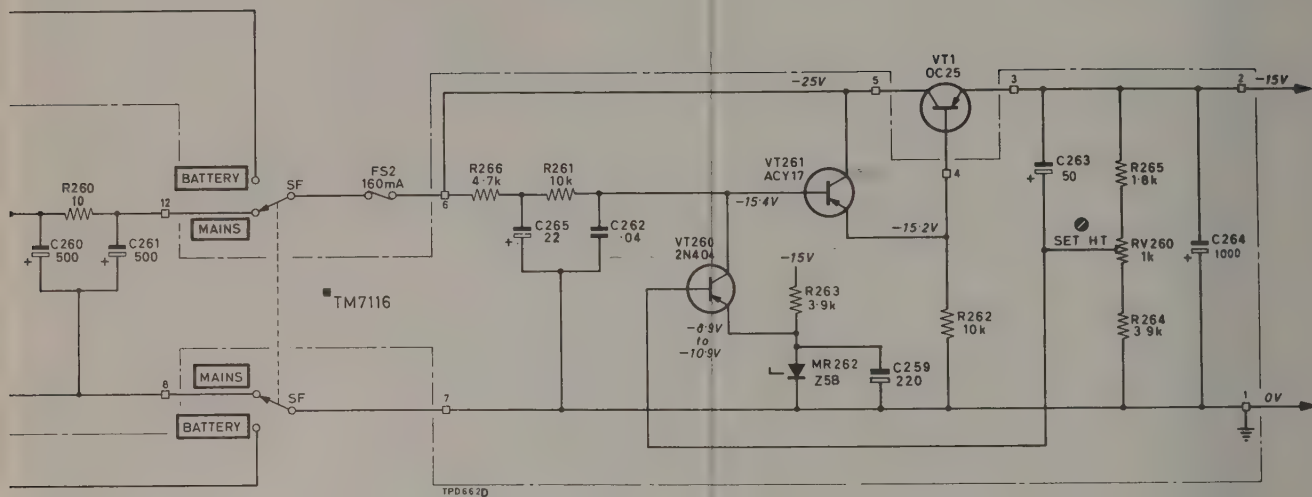
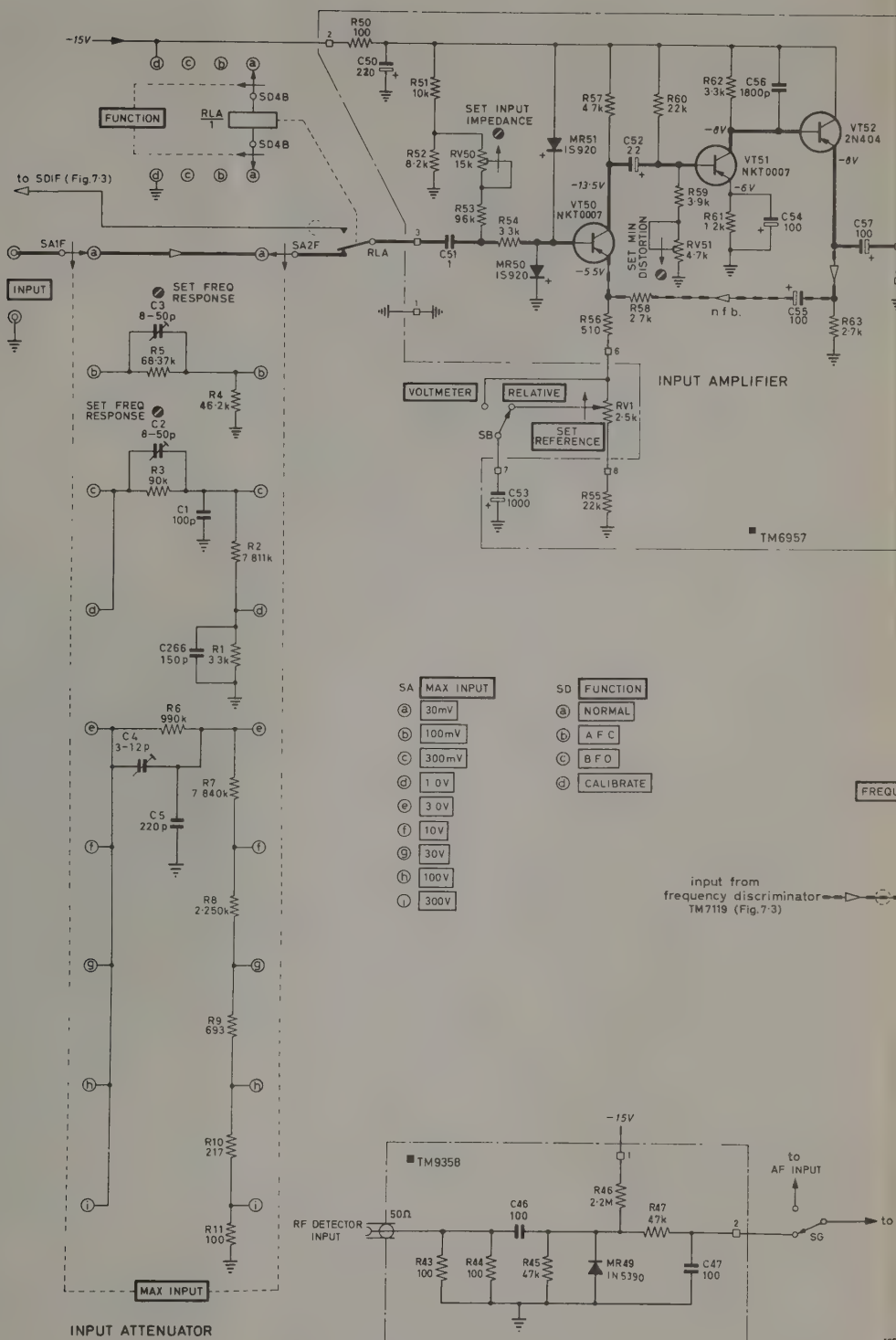


Fig. 7.1 Power supply



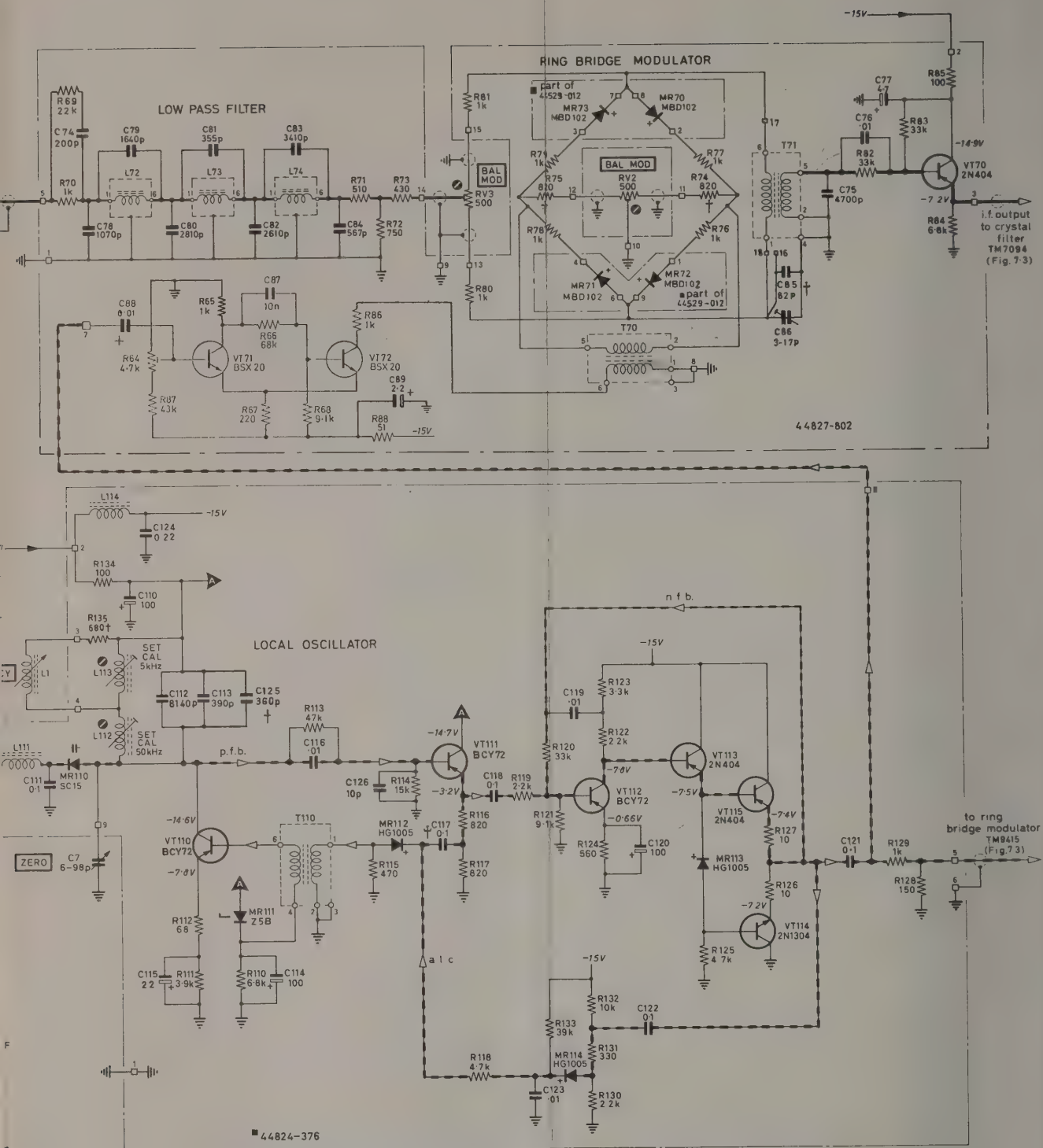


Fig. 7.2 Input stages

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